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STUDIES OF IRRITABILITY IN ALGAE.

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(WITH TWENTY-SEVEN FIGURES)

INTRODUCTION.

IN a recent book on the physiology of plants (**13**) the statement is made that "when zoospores and other motile and floating spores of sessile plants come to rest, attaching themselves to the substratum, the attachment is effected through means not yet wholly clear. . . . It remains for experiment actually to show that the increased rate and the changed direction of growth in such cases among plants are due to contact, though it seems to be the case in animals" (**10**).

It was with a view to adding somewhat to our knowledge in this direction that the studies here reported were undertaken, first with fresh-water algae, and subsequently with marine. We worked together on the fresh-water algae; one of us worked alone on the sea-weeds;[1] we have gone over all the results together.

For the sake of clearness, we may briefly describe the series of events, a small part of which we wish to report in some detail. Zoospores of Oedogonium, Vaucheria, and other fresh-water algae, after escaping from the cells in which they form, may swim about for a considerable length of time. If they are in the light, the direction of their locomotion is influenced by the direction and intensity of the light which falls upon them. This has long been known, though

[1] I take this opportunity to express my appreciation of the opportunity of studying, during October and November 1904, at one of the tables maintained at the Zoological Station in Naples by the Carnegie Institution, Washington. I wish also heartily to thank the officers of the Zoological Station for the courtesy which they showed me.—G. J. P.

even now far from perfectly understood (**7**). When the zoospores come to rest, they surround themselves with a cellulose wall. If they come to rest in contact with a solid object, their form changes as well; the part against the solid flattens and adheres to it. Thus a holdfast is formed. The young plant, now sessile, may pass rapidly by successive periods of cell-division and of growth through the subsequent stages of its development. The activities of zoospores, then, are greatly influenced at different times by various agents; the direction of their locomotion is determined by the intensity and direction of the light falling upon them, the formation of cell-wall immediately follows their coming to rest; the growth of the foot or holdfast is proportioned in form and extent to the roughness of the surface with which the zoospore is in contact; and the direction of the first cell-division is probably determined mainly by the light. These last three points we shall discuss in detail.

Turning for the moment to the behavior of the non-motile spores of marine algae, such as those of Fucus, Cystoseira, Dictyopteris (Halyseris), we see nearly the same phenomena exhibited. There is no independent locomotion, and hence the transport of the spores from their points of origin to where they are to germinate is not directed by the influence of light upon them, but by water currents. The formation of the cellulose wall, the growth of the foot, and the direction of the first cell-division (**20**) are, however, determined by the same influences as those controlling the similar phenomena among fresh-water algae. These we hope the following pages will make clear. We shall report first upon the fresh water algae, as it was upon these that we began our work.

I. FRESH-WATER ALGAE.

MATERIAL AND METHOD.

Vigorous plants of Oedogonium, somewhat crowded by diatoms and other low forms, were found in watering-troughs for horses in paddock or on pasture in the vicinity of Stanford University, California. Many of the plants were growing attached to the sides of the troughs, submersed but near the surface of the water, in some cases fully exposed to the light, in others partly shaded by trees. Other Oedogonium filaments were found attached to dead leaves

floating near the surface of the water in the troughs. This water was quiet and fairly clear. The level of the water, tending to be lowered by evaporation or by the draughts of the few horses using the troughs, was automatically maintained by ball-valves, similar to those used in houses. A few other plants, apparently of the same species, were found in a quiet pool in the San Francisquito Creek, growing on stones in comparatively clear water.

The material was brought fresh into the laboratory from time to time from mid-September till mid-November, and again from early April till late in May. Since the material did not fruit in our cultures, and we found none fruiting out of doors, it was impossible to determine the species, though we tried to have this done for us. We regret this lack of definiteness in our work.

METHOD OF MANIPULATION.

Plants brought into the laboratory were placed in an abundance of tap-water in glass dishes covered with a glass plate or loose cap to prevent excessive evaporation and to exclude dust. Small Stender dishes were largely used, since these could easily be placed under the microscope, thereby avoiding such disturbance of the material as transfer from one dish to another would entail.

Fortunately for us the water from the tap was from the same source that supplied the horse-troughs, and the creek contains mainly the overflow from the artificial lake which is the general water-supply for the region. When, therefore, our plants were brought in and put into tap-water in the laboratory, they were put into water of the same composition and approximately of the same temperature and degree of aeration as the water of the troughs and the pool from which they had been removed. The behavior of our plants was immediately affected only by those factors changed by the transfer to the laboratory, not by the water, though it goes without saying that the temperatures of the cultures in the laboratory never fell quite so low at night during the winter and spring as that of the water outside in troughs and pools.

Cultures were also made in Knop's solution,[2] 1 per cent. and 0.5 per cent. In certain cases we added 10 per cent. gelatine or 0.25 per cent. agar-agar to the Knop's solution, in order to obtain a

[2] 4 parts calcium nitrate, 1 part potassium nitrate, 1 part magnesium sulphate, 1 part potassium phosphate.

solid culture medium. These solid cultures were made in Petri dishes. Although such dishes have the same advantage as Stender dishes in that they can be put under the microscope and the cultures studied without disturbance, they cannot safely be employed in an ordinary laboratory for more than very brief periods at a time. The air of the ordinary laboratory is excessively dry (**2**). In consequence, there will be a quite too rapid and altogether excessive concentration of the culture medium in Petri dishes, even if covered, in all cases in which experiments last for more than a few days. In our climate, the air in the laboratory in which we worked is more humid during the winter (the rainy season) than in most laboratories. We therefore ventured to continue these cultures for some time. In summer and autumn here, and at all seasons in most laboratories elsewhere, Petri dishes are unsuitable for the culture of algae. They should be replaced by flasks holding a much larger volume of the moist culture medium and furnished with narrow necks closed by very tightly rolled cotton plugs. At certain seasons it would be well to cover the plugs with the rubber caps made for that purpose.

All dishes and solutions were carefully sterilized before the algae were sown in them. Instruments were sterilized immediately before use. In this way few if any organisms were added from outside when fresh cultures were made; but as, in order to save time, we started with small masses of material rather than with single cells or single filaments, our cultures were not pure. We experienced considerable annoyance in a few instances from the growth of bacteria or of algae other than the ones especially sought. Nevertheless, for such experiments as we had in mind, the extreme pains and the long time required to obtain pure cultures would hardly be justified by results. Furthermore, the behavior of living organisms in pure cultures may be due in part to two unnatural, that is to say unusual, factors, namely, the artificial culture medium and the vessel in which it is contained, and the freedom from the competition with other kinds of organisms and their products. Our aim was, therefore, to grow our algae under as nearly as possible natural conditions, though we realize that the degree of naturalness which we attained is only one stage in advance of the frank artificiality of pure culture.

One of the greatest difficulties encountered in the culture of green

plants of any grade of complexity in a laboratory not provided with a greenhouse is in securing proper illumination, a difficulty all the greater when one realizes that not only is normal growth dependent upon adequate illumination, but many of the other phenomena of life are greatly influenced by it. As KLEBS (**8, 9**) and VÖCHTING (**19**) go far toward proving, the reproductive processes, as well as the behavior of the reproductive elements, are profoundly sensitive to light. Therefore, in any series of experiments involving irritability—that is to say, in every series of experiments on living organisms—the illumination must be carefully considered. Not having any greenhouses connected with our laboratory, our difficulties were increased. Furthermore, in our climate, there is a great contrast between the light of the rainy and of the bright days in winter, while in spring and summer, the direct sunlight is quite too intense for algae except in running water or in large bodies of still water. Between too little light at a short distance from a window and too much light near it, the right illumination is difficult to find. We attempted to attain this by placing our culture dishes on glass shelves in a window looking southeast, screening the dishes at times of bright sunshine by a sheet of white tissue paper pasted across the lower part of the window.

BEHAVIOR OF THE ZOOSPORES.

Locomotion.—While motile, the zoospores are evidently sensitive to light, moving toward the more strongly illuminated side of a slide, or coming to rest, when possible, on the light side of the dish in which they escape. This is a general statement of a result of our observation; but, as has been known since STRASBURGER'S classical study (**18**) of the behavior of swarmspores, they move toward light of a certain intensity rather than light of greater intensity, turning away from spots too intensely illuminated toward comparative darkness, just as they turn from comparatively dark spots to more suitably illuminated ones. Since there are still no means of accurately measuring either the intensity or the quantity of light falling upon a given spot, it is out of the question to determine what the minimal, optimal, and maximal illuminations are for motile zoospores, for their production, or for the parent plant. We must, therefore, content ourselves with reporting such general observations as we were able to make.

The duration of swarming has been reported by various authors (**15**, p. 768), among them STRASBURGER, who found active swarm spores of *Ulothrix zonata* after three days, of *Haematococcus lacustris* after two weeks, during which the material had been kept continuously in darkness. These figures have little significance beyond the fact that the plants produced motile zoospores during this time. The duration of swarming of the individual spores is quite unknown. On this point we can give little information. We found, however, that in our Oedogonium the zoospores came to rest and attached themselves within fifteen to eighteen hours, *i. e.*, zoospores which had escaped and were active in daylight came to rest and attached themselves during the succeeding night.

The spot to which zoospores formed in water attach themselves is largely determined by the direction and intensity of the light, if there be any, which falls upon the culture. If light of not too great intensity fall upon a dish horizontally or nearly so, the zoospores will collect and come to rest mainly upon the more strongly illuminated side. If on the other hand the light fall vertically or only somewhat obliquely from above, the zoospores will collect at the surface of the water. It is frequently observed, when the light falls obliquely upon a culture of algae, that the zoospores collect in greatest numbers at the surface of the water on the more brightly lighted side. From this the attractive influence of the oxygen of the air might be inferred. That such an inference is not always justified is proved by the fact that when the light falls horizontally, or is reflected obliquely from below upon a culture, the zoospores still tend to collect at the point best lighted, regardless of the greater oxygen supply near the surface of the water. As to the directive influence of oxygen upon the locomotion of zoospores, we made no experiments, but it is clear from this observation that in general the directive influence of light is stronger than that of oxygen. When, therefore, zoospores come to the surface of the water, they do so mainly under the influence of light. Their behavior on reaching the surface, which is decidedly different from that of the zoospores coming to rest elsewhere, we shall presently describe.

Germination.—When zoospores come to rest, the cilia are absorbed, the naked masses of protoplasm surround themselves by cell-walls, the forward end of each zoospore develops a holdfast attaching it to

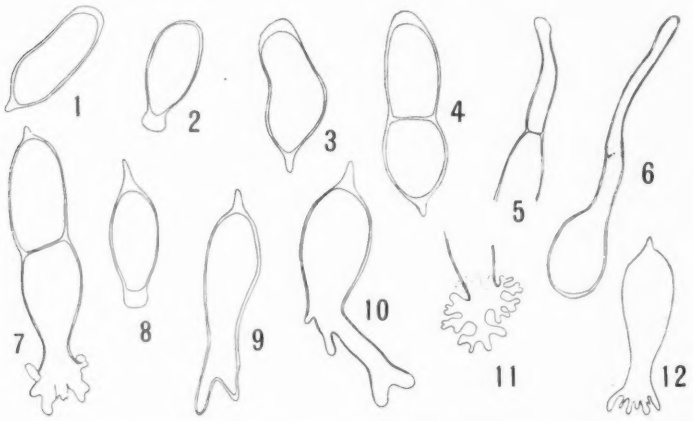
the surface with which it has come into contact. As light evidently directs the locomotion of the spore, it is reasonable to suppose that it also determines its polarity on germination. It is hardly probable that light influences the growth of the holdfast; nor has gravity any effect, for the spores attach themselves in various positions and may even be suspended from the surface of the water. Chemical stimulus can hardly have any part in the matter, except perhaps in relation to the bacteria. The growth of the holdfast would appear, then, to result from contact with a solid body, as an irritable response to contact stimulus. This matter we wish to report upon at length.

The influence of contact upon growing plants and their parts has been studied from various points of view by many investigators and upon a great variety of plants. It is now clear that contact with a solid object may influence growth in three ways: first, as to its direction, as shown by sensitive tendrils (**16**); second, as to its rate, also as shown by tendrils (**5**); and third, as to its kind, as shown by the formation of haustoria in dodder (**14**). Contact similarly influences the direction, rate, and kind of growth in germinating zoospores.

If it is true that contact influences the direction, rate, and kind of growth in germinating zoospores, the character of the surface with which the contact is effected should be reflected in the germinated zoospores, a rough surface producing a different and more pronounced effect than a smooth surface. To test this hypothesis, we used a variety of substances for the purpose of catching the zoospores, viz. wisps of cotton, clean cover glasses, glass roughened by corrosion and deposit, strips of gelatine, freshly split mica, and the surface of the water itself. These we interposed between the swarming spores and the light. The spores came to rest and attached themselves within eighteen hours.

Zoospores germinating on the surface of the water in contact with dust particles, diatoms, and masses of bacteria developed long slender processes, sometimes forked, but always hypha-like in appearance (*figs. 5, 6*). Others on the surface, and in contact with no solid matter whatever of visible amount, formed the most rudimentary hold-fasts, knob-like processes of very small size (*figs. 1, 2, 3, 4*). Those on gelatine, the acid reaction of which had been duly neutralized, formed

knob-like or filamentous processes in lieu of holdfasts on clean spots on the gelatine (*fig. 8*), whereas those in contact with particles of dirt were more or less branched (*figs. 9, 10*). On roughened glass many zoospores developed disks (*fig. 12*). On clean glass the regularity of these disks was very striking (*fig. 11*). Irregularity of surface evidently induces irregularity of growth and form. This appears even more plainly from the experiments on marine algae (p. 343).



FIGS. 1–12.—Germinating zoospores of *Oedogonium sp.*? ×780.

1, 2, 3. Germinated on the surface of water (1, 2 filtered, 3 unfiltered) showing extremely rudimentary holdfast.—4. Same somewhat older, divided into two cells.—5, 6. Same but with hypha or rhizoid-like outgrowths at the basal end of each spore. Bacteria surround these filamentous processes.—7. Germinated on freshly split mica. Note well-developed holdfast.—8. Germinated on clean wet gelatine.—9. Germinated on a spot of dirt on wet gelatine.—10. Germinated on spots of dirt and bacteria on wet gelatine.—11. Germinated on clean cover glass. Note extremely regular holdfast.—12. Germinated on side of roughened glass dish. Note irregular holdfast.

Even clean glass and freshly split mica are not absolutely smooth. The dustless upper surface of clean water is smooth. So also is clean wet gelatine, as PFEFER'S work on tendrils showed (**16**). On these two no holdfasts are formed by germinating zoospores. In place of holdfasts longer or shorter hypha-like filaments appear, often very short indeed, and branched only where the surface is roughened by dust or dirt. On carefully polished clean cover glasses, holdfasts of remarkably regular form were developed. As will be shown later (p. 344), uniformly ground cover glasses used in experiments with

the less irritable germinating spores of marine algae induced the formation of very regular holdfasts. We may say then that the form, size, and even the development of holdfasts by sessile fresh-water algae depends upon the character, the degree of roughness, of the surface with which the zoospores come into contact. A uniform though slightly rough surface, like that of clean polished glass, will induce the formation of very symmetrical holdfasts. Coarsely or irregularly roughened surfaces induce the formation of irregular holdfasts. Extremely smooth surfaces fail to induce the formation of holdfasts, unless perhaps of the most rudimentary sort. It would seem clear then, that so far as the direction and kind of growth are concerned, contact acts as a stimulus; for the holdfast grows parallel with the surface, no matter how irregular this may be, and the organ produced corresponds to the surface on which it is formed, being simple or branched, symmetrical or irregular, according to the character of the surface. As to the effect of contact upon the rate of growth, we can say nothing so far as fresh-water algae are concerned. The measurements of growth rates among marine algae are given subsequently (p. 347).

From the observations thus reported, it is obvious that contact acts as a very important stimulus in the germination of the zoospores of sessile algae. The value of this to the plant is evident enough. If, however, we could induce algae ordinarily not sessile to form rhizoids or other holdfasts by bringing them into contact with suitably roughened surfaces, and if we could find, in nature,[3] algae ordinarily not attached fastening themselves to rough surfaces occasionally, we should add materially to the significance of our observations. Both of these things one of us has done. Though reserving the subject for further study, we may report now that plants of a species of Spirogyra which did not fruit and hence could not be determined while we were working upon them, formed rhizoids in our cultures, and were found to have formed rhizoids out of doors, wherever the filaments were in contact with sufficiently rough material, clean cover glasses, trough-scrapings containing lime, diatoms, etc., and similar

[3] Since this part of our work was ended, at least for the time, COLLINS's paper in Rhodora (**6**:230. 1904) records the formation of holdfasts by Zygnema filaments growing against rock in a swiftly running stream.

material. We have never seen rhizoids on floating filaments or on the free floating parts of attached filaments. The size, form and direction of growth of the rhizoids were greatly influenced by the nature of the surface which the cells of Spirogyra touched, clean glass inducing the formation of strikingly regular crenate disks on the ends of the rhizoids like those formed on the same material by *Oedogonium*. Dirty glass, on the other hand, induced the formation of proportionally irregularly branching holdfasts. Thus our observations confirm the generally unknown observations of BORGE (**3**), who in 1894 reported his studies of a species of Spirogyra which formed rhizoids. BORGE'S paper contains a list of earlier authors who mention having seen rhizoid-bearing Spirogyra.[4]

From the fact that on extremely smooth surfaces like the surface film of clean water or of wet neutral gelatine, no true holdfasts form, and that on sufficiently rough surfaces even such a plant as Spirogyra may form organs of attachment, it is clear that the growth of rhizoids or holdfasts represents the reaction of a plant to the stimulus of contact. The germination of a zoospore of a sessile alga is influenced by contact; but contact, though it stimulate the zoospore to form an organ of attachment, is not needed to cause the zoospore to germinate. The zoospore may remain in motion for a long, but at present unknown, period of time. So long as it continues to move about, it does not germinate. When its locomotion is stopped, germination begins. When a zoospore reaches a very smooth but impenetrable sheet of gelatine interposed between it and the source of light falling upon a culture-vessel, it loses its cilia, ceases to move, and surrounds itself by a cellulose wall — it germinates; but unless it has stopped upon a particle of dirt on the surface of the gelatine, it puts out at best only a rudimentary hypha-like process, a rhizoid, not a holdfast, and this it does after germination has begun. Similarly, if the further progress of a zoospore toward the light be opposed by its having reached the top of the water in which it was found, the zoospore will cease to move, will lose its cilia, will surround itself with a cellulose wall, will germinate; but it will not form a holdfast or even a rhizoid

[4] Subsequent papers by BORGE figure other species of Spirogyra with rhizoidal holdfasts (Die Algen der ersten Regnelschen Expedition. Archiv för Botanik 1:—— 1903).

unless it has happened to land upon particles of dirt or other solid. Germination, then, follows enforced cessation of locomotion; growth, so far at least as the formation of a holdfast is concerned, follows and is dependent upon contact irritation.

Let us turn now to the marine algae.

II. MARINE ALGAE.

MATERIAL AND METHOD.

The material consisted of fresh fruiting plants brought in almost daily from the Bay of Naples. These plants, when not used immediately, were put into well-lighted aquaria, supplied with running sea-water, where they remained healthy for days after they had ceased to be used. The plants were *Dictyopteris* (*Halyseris*) *polypodioides*, *Dictyota dichotoma* (two varieties at least of this extremely variable form), *Cystoseira barbata*, *C. erica marina*, among brown algae; and *Laurentia obtusa*, *Polysiphonia* (sp.?) among the red. I tried to get zoospores of Ulva, Cladophora, and other green algae, for the sake of comparison with the behavior of the zoospores of fresh-water algae; but whether owing to the season of the year (October, November) or to other causes, I do not know—at all events, I failed to get sufficient numbers to justify any conclusions. The spores used were of two sorts, the fertilized eggs of the two species of Cystoseira, and the non-sexual spores and tetraspores of Dictyopteris, Dictyota, Polysiphonia, and Laurentia. Their behavior is essentially similar.

BEHAVIOR OF THE SPORES.

Influence of light upon their escape.—I began my work with *Dictyopteris* (*Halyseris*) *polypodioides* and the two species of Cystoseira. Clean fruiting branches, as free as possible from diatoms and other organisms, were put in small dishes about 4^{cm} diameter and 2^{cm} depth, filled with fresh sea-water. To reduce evaporation the dishes were covered either with glass caps or clear glass plates. The dishes were set on a broad shelf inside a northwest window about 13^{cm} below the lower edge of the glass. The light fell therefore somewhat obliquely upon the cultures. At noon on sunny days I closed the screens, made of sheeting, in order to prevent the sun shining directly upon the dishes during the afternoon. I found this

illumination satisfactory. If the fruiting branches are put in the dishes late in the afternoon, enough spores will escape by nine o'clock next morning to justify removing the branches. In this way the age of the escaped spores may be confined within fairly narrow limits. If it were desirable to limit the age of the spores still more, as was sometimes the case, I made the cultures as soon as the fresh material was brought in, in the forenoon, and left them for four hours on the window shelf. In this time many spores escaped from good material, and I removed the fruiting branches. The dishes were left otherwise undisturbed for 22 or 24 hours after the cultures were made, in order to allow as many spores as possible to stick closely by their slimy coverings to the bottoms of the glass dishes. At the expiration of this time, the water in the dishes was carefully decanted, and fresh sea-water poured in. A considerable number of spores may wash out in this first change, but presumably they are the youngest, the ones last escaped from the fruiting branches, and there is the advantage in losing them that the material left in the dishes is still more nearly of the same age. Within these 24 hours the spores of Dictyopteris will have begun to germinate, putting out a short blunt process which is to form the holdfast, and having divided into two or three cells. Cell-division, so far as the formation of a dividing wall is concerned, does not seem always to precede the appearance of the process which is to become the holdfast; but there seems to a be slight difference in this regard between spores germinating under the ordinary conditions of alternating daylight and darkness and those kept constantly in darkness. The latter generally form the division wall before putting out the process, but to this rule there are many exceptions. In Dictyota and Cystoseira, however, the division wall is always plainly visible before the rhizoid appears.

The escape of the spores of Dictyopteris is much less abundant if the dishes are left in the dark than if they are normally lighted. Thus, on November 11, at 12 o'clock, I put as nearly as possible equal quantities of fruiting Dictyopteris in eight dishes, two of which I set on the window shelf and six in the dark. At 10 o'clock the next morning I counted the spores in all the dishes. There were 444 and 75 spores in the dishes set on the window shelf. In the six dishes kept in the dark for these 22 hours there were 59, 134, 287, 135, 219,

218 spores. The first three of these dishes I then set on the window shelf, putting into each the same pieces of Dictyopteris that had been in them. The other three I set back in the dark, putting into them the same branches which they had previously contained. All the dishes had fresh sea-water put into them. At 5 o'clock that afternoon so many spores had come out in the dishes in the light that I removed the pieces of Dictyopteris from all six and left them undisturbed until November 14 in the morning. Then I counted the spores, practically if not quite all of which had become fastened to the bottom of the dishes. There were now in the dishes in the light 1565, 2046, and 2245 spores; in the dishes in the dark 866, 1716, and 596 spores. In the dishes put into the light after darkness there were now 5856 spores where there had been only 480 before, a gain of 5376 or 11.2 times as many. In the dishes kept in the dark there were now 3178 spores, a gain of 2606 or 4.5 times as many. Nearly two and a half times as many, therefore, had come out in the light as in darkness in the same length of time.

The counting of such large numbers of small spores, especially where they lie very close together, is not easy. To facilitate counting and to bring the count to an approach to accuracy, I ruled lines about 2.5^{mm} apart with India ink on the bottoms of the dishes. The counting was done over a white surface with a hand-lens magnifying about fourteen times.

To ascertain whether the amount of light has any effect on the discharge of spores, I put fruiting branches of Dictyopteris in dishes in the dark, in the full diffused light on the window shelf, and under black hoods which had a vertical slit on one side about 3^{mm} wide and 15^{mm} long. I did not count the spores, but it was evident that most had escaped in the dishes in full light, fewest in the dishes in the dark, and a quantity between these two in the diminished light.

Similar experiments with *Dictyota dichotoma* yielded results similar in every respect.

As indicating the relation of light to the process of extrusion of the gametes I may report some of my experiments on Cystoseira. On November 8, at 11 o'clock, I put fruiting branches of *Cystoseira barbata* in four small dishes, two of which I set in the dark, two on a shelf by a window, taking pains to have as nearly as possible equal

numbers of fruiting tips in the different dishes. At the same time I similarly prepared four dishes of *Cystoseira erica marina*. In two hours and three quarters there were evidently many more spores (eggs) in the lighted dishes of *C. erica marina* than in those in the dark, but apparently about equal numbers in the two sets of dishes of *C. barbata*. At about 10 o'clock the next morning I removed the branches of *C. erica marina* from the dishes, throwing away those that had been kept in the light, and poured off the water from the four dishes. I counted 99 and 50 eggs in the two dishes which had been kept in the dark, 454 and 420 in the dishes kept in the light. The latter two had of course been dark for nearly or quite twelve hours, from sunset to sunrise. The branches which had been in the darkened dishes I put back in these dishes, with fresh sea-water, and set them on the window shelf. Four hours later many eggs had come out and I therefore removed the branches, but left the dishes quiet till the morning of the 10th, so that the eggs might settle and become fastened to the bottom of the dishes. On the morning of the 10th, I poured off the water, preparatory to counting the spores. Many spores were carried away by this means, but those attached to the bottoms of the dishes now numbered 270 and 241 respectively.

I made similar counts of the number of eggs of *C. barbata* escaped and attached in the dishes darkened for twenty-three and one-half hours. There were 426 and 348 in the two darkened dishes. There were so many spores in the dishes which had been exposed to the daylight till sunset and after sunrise that I contented myself with counting those in the first three spaces from one side of one dish. In this space there were 376 spores. This area equals about one quarter the area of the bottom of the dish. The spores were not equally distributed over the bottom, but there were at least four times as many over the whole area. There were therefore about four times as many spores in the dishes which had been in the daylight as in the constantly darkened dishes. As with *C. erica marina*, I put back the fruiting branches which had been in the darkened dishes, filled them with fresh sea-water, and set them on the shelf by the window. Three hours and a half later I took out the branches, leaving the spores which had escaped to settle in the dishes and to become attached. The next morning I counted the spores attached to the bottom of

the dish, in which 426 spores had escaped and attached themselves in the dark. There were now 1574 spores. In three hours and a half, therefore, after putting the dishes in the light, 948 spores had escaped and become fastened to the bottom, more than twice as many as had escaped in twenty-three and one half hours of darkness.

That the number of spores which had escaped was far greater than the number which had attached themselves is shown by the other dish. From this dish I carefully decanted rather more than half the water and shook as many as possible of the loose spores into a space about 6^{mm} square. In this space a single layer of spores covered the whole area of $36^{sq\ mm}$. Half the area had two layers of spores, and one quarter had three layers. If these spores had been spread out in a single layer, they would have covered an area of $63^{sq\ mm}$. The average diameter of the spore is 0.09^{mm}. Calculating the area of a spore and dividing this into $63^{sq\ mm}$ we find that there were about 2623 loose spores in this area. There were many more loose spores than I could collect in one spot by shaking, so that the calculated number of practically spherical spores is none too large, though they could not occupy the whole of any quadrangular area. There must have escaped therefore at least 3400 spores during three hours and a half of daylight in the dish in which I had counted 348 spores, twenty-three and a half hours after the dish had been put in the dark. At least eight times as many spores had come out, therefore, in three and a half hours of daylight after darkness as in nearly seven times as long a period of darkness.

It is to be noted that this very large number of spores (egg-cells, probably fertilized) was obtained only after an abrupt change from protracted darkness to full daylight. In nature, except in polar regions, the darkness is never so prolonged; and nowhere in nature is the change from darkness to daylight so abrupt. Whatever effect darkness and light have upon the discharge of the gametes must be exhibited in maximum degree in such an experiment as I have just described.

We see, then, that light has a decided influence on the time and the rate of discharge of gametes (in Cystoseira) and of non-sexual spores (in Dictyopteris and Dictyota). In Fucus it has long been known that the majority of the gametes escape and fertilization takes place

soon after sunrise. OLTMANNS (**12**, p. 523) speaks of a periodicity in the discharge of the gametes of the constantly submersed Fucaceæ (Halidrys, Cystoseira, etc.) as well as in Fucus. Fucus does not occur in the Bay of Naples, though abundant enough in most other parts of the ocean. It is ordinarily twice daily exposed at low tide, but as various authors[5] have shown such uncovering is not necessary to the discharge of the gametes. The mechanism of the discharge of the gametes consists, in part, in the swelling of the gelatinous material in the conceptacles and the compression of the walls of the conceptacles by the surrounding tissues when the sexual elements are ripe. OLTMANNS expresses doubt whether these two factors alone furnish an adequate explanation of the process. As the matter now stands, these mechanical means do not account for the periodicity, unless we assume the relation of light to the processes connected with the growth of the gametes and with the formation of gelatinous matters within the conceptacles.

The periodicity coincides with the sequence of light after darkness, and is as evident, as my experiments have shown, in forms having no conceptacles as in those that do have them. In Dictyopteris, the aplanospores (tetraspores) form on both surfaces of the flat thallus, near the midrib, and project more or less from the surfaces as they grow. Finally they escape through a slit in the wall of the mother-cell. They may even germinate (**12**, p. 486) before escaping. It is difficult to see where mechanical pressure can effectively develop here except in the sporangium itself, that is, by the growth of the spores and the gelatinization of the wall and residual contents (if any) of the spore mother-cell. I shall subsequently show that light favors the germination of the spores and the growth of the young plant, though they will germinate and grow in darkness. It is probable, therefore, that light favors the growth of the spores before they escape from the sporangium as well as after. In this we have a partial explanation of the connection of the periodic discharge of the spores in Dictyopteris and of the gametes in Fucus and Cystoseira with the mechanical means of discharge above discussed. The influence of light is favorable to the growth of the spores, therefore to the development of mechanical pressure by them, but as the rapid discharge of

[5] Cited by OLTMANNS, *l. c.*

spores occurs within a few hours after the fruiting material has been put into the light after being in darkness, it may be objected that there is not time for sufficient growth to take place to develop the necessary mechanical pressure, if mechanical pressure has anything to do with the matter in such plants as Dictyopteris. In reply to this possible objection, I may say that, though the spores are rapidly discharged within a few hours, there was no evident increase in the accumulation of spores in my dishes until at least two hours had elapsed after they were put in the light. There is therefore time for growth.

To make this point clear I will report one experiment. Three small dishes of fresh fruiting Dictyopteris branches were kept in the dark for twenty-two hours. Early in the morning, the material was removed from these dishes, in which a considerable number of spores had been discharged, and placed in three clean dishes of fresh sea-water on the window shelf in the light. From these dishes the fruiting branches were removed after the lapse of one hour and put in another set of three dishes, the first set being left otherwise undisturbed to allow the spores which had escaped to settle and become attached. The same was done at the end of each of the two hours following. At the end of another hour and forty minutes, I repeated the process, and again after the lapse of two hours more. I therefore had five sets of three dishes each, in which spores had escaped. The number of spores at the time of exposure to light are as follows:

After 1 hour's exposure to light	36	spores in	3	dishes
" 2 hours' " "	26	"	3	"
" 3 " " "	170	"	3	"
" $4\frac{2}{3}$ " " "	1671	"	3	"
" $6\frac{2}{3}$ " " "	597	"	3	"
Total number of spores in 15 dishes	2500			
Total number of spores in escaped last $3\frac{2}{3}$ hours	2268			
Percentage of spores escaped in last $3\frac{2}{3}$ hours	90			
Percentage total time in which these spores escaped	55			

From these figures it is clear that the discharge of the spores in the light is not an immediate one, but that a certain length of time must elapse after the plants are brought into light after darkness before they begin to discharge their spores rapidly. What changes take place under illumination which result in the discharge of the

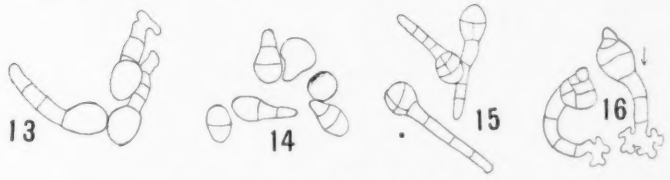
spores, I do not venture even to guess. On this interesting point I have no data.

It may be that in addition to the influence of light on the processes of food manufacture and growth in the spores and in cells adjacent to the sporangia, there are irritable responses which contribute to the development of the mechanical pressure which causes the spores to be discharged. Information on this point might add to our meager knowledge of the phenomena of irritability in the marine algae.

I am by no means satisfied that the plant does not irritably respond to the light by more immediate means than growth. The light may also favor gelatinization, but the connection with this process, the details of which are unknown, is not sufficiently clear to justify discussion now.

The influence of light upon the germination of the spores.—The germination of the spores of Dictyopteris has been adequately described by REINKE (**17**), but he naturally made no attempt to ascertain the influence of the different factors of the environment upon the course of germination and upon the form of the young plants. In order to learn something about these matters I compared spores which had escaped during twenty-four hours in different dishes as to their rate of germination and the development of the young plants in the light and in darkness. In *fig. 13* we have young plants shown which had developed thus far in a dish completely covered by black paper except for a vertical slit 17×6^{mm} on the side of the dish toward the window. The time since sowing was three and three-quarters days. In *fig. 14* are shown young plants from spores escaped at the same time, but in dishes kept completely darkened. It may be objected that the conditions of the two experiments were not the same, and therefore the results may not be comparable. I have shown above that light favors the escape of the spores, probably because it favors their growth. For this reason, therefore, the results are exactly comparable, because the point is made still clearer that the germination of the spores is more rapid under the normal daily alternation of light and darkness than in continuous darkness. For the germination of the spores of ferns (**4**, p. 423–4), the seeds of Viscum, and for various other plants it is claimed that light is necessary. This is not generally the case with higher plants. As *fig. 15*

shows, the young plants grown in the dark for five days were only as far along as those grown for three and three-quarters days under the black cap with a slit in the side. *Fig. 16* shows plants five days old grown under the black hoods with a side slit. This difference in growth rate may be due to two factors at least. In the first place, no manufacture of non-nitrogenous food can take place in the dark, though some such food may be manufactured even in the dim light under the black cover. If such food were manufactured, it could be used at once to nourish the organism, which is supplied in the spore with only a comparatively small amount of food. In the second place,



FIGS. 13–16.—*Dictyopteris* (*Halyseris*) *polypodioides*. ×123.

13. Germinating spores sowed 3¾ days earlier on ground glass in dish receiving light only through vertical slit on one side, 17×6mm; direction of light indicated by arrow. Note that all rhizoids point away from light, whereas the nearly erect plantlets are inclined toward the light.—14. Same in every respect, except that it was kept constantly in darkness. Note smaller size of plantlets. 15. Same, five days old, constantly in dark. Size about same as lighted plantlets 3¾ days old.—16. Same as 15 but in dish lighted through vertical slit, 17×6mm. Plantlets strikingly further advanced, erect but inclined toward light; direction of source of light indicated by arrow.

if the manufacture and assimilation of nitrogenous food is more rapid in the light than in darkness, as is now claimed,[6] those spores in the light would be better off than those in darkness.

Whatever the reason may be, the young plants grow and develop faster in normally alternating light and darkness than in continuous darkness. This fact, not altogether in harmony with certain current views of the influence of light and darkness upon growth (**11**), deserves much more extended study. It seems to us probable that the opinions of plant physiologists, based too exclusively on studies of land plants, will be modified when the algae, especially the marine algae, have become as familiar to them as aquatic animals now are to other physiologists.

Having seen that light favors germination and growth, we may now inquire what other effects it has. If spores sown in dishes in the

[6] GODLEWSKI's papers in Bull. Acad. Sciences Cracow, 1903, and earlier and later.

manner previously described are exposed to one-sided illumination, the holdfasts will appear always on the side away from the light. If spores germinate in darkness, the holdfast will be put out in all possible directions from different spores. This result I have repeatedly obtained in Dictyota, Dictyopteris, and Laurentia, as well as in two species of Cystoseira, thus confirming and extending WINKLER'S (**20**) interesting experiments on *C. barbata*. The gelatine method which WINKLER used for part of his experiments is apparently more exact than mine, but what it gains in apparent exactness it loses in naturalness. The spores in a layer of sea-water not too thin (as it may be on a slide, especially if this is covered) quickly adhere to the surface of clean smooth glass, and if the dish remain undisturbed for several hours they are not likely to be dislodged by ordinary movements afterwards. The use of gelatine, or of any other similar material even in dilute solution, such as WINKLER describes, is open to suspicion by reason of the facts reported in the foregoing part on fresh water algae, and also because of the results of BORGE (**3**) already referred to, although WINKLER reports the germination as perfectly normal. Naturally, for his gravitation experiments, a solid medium was necessary, but not for those on light.

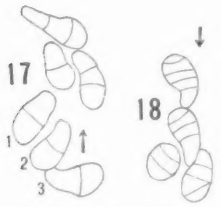
To escape the legitimate objection that the spores may behave differently in darkness and in light, I put upon the horizontal plate of a clinostat a dish in which Dictyopteris spores had escaped during twenty-four hours in darkness, covering the dish with a black sheet of cardboard so that all the light came from the side. The plate of the clinostat was also covered with dull black paper to avoid possible reflection from below. The dish was therefore revolved in a horizontal plane and received light not only from the side, but on all sides successively. The clinostat was very simple — an alarm clock from which face and hands were removed, a sleeve carrying a thin zinc plate being soldered to the minute hand spindle. The dish was therefore revolved once an hour. The result was that the germinating spores sent out holdfasts in all possible directions, some of the rhizoids growing upwards, others downwards, the majority horizontal until their increasing weight tipped the spores sufficiently to bring the ends of the rhizoids into contact with the glass.

It appears, then, that the side of the spore which is to give rise

to the holdfast is ordinarily determined by light, which in nature falls from above, vertically or more less obliquely. The direction of growth of the rhizoid is also determined by the light, other things being equal, and this frequently brings it into a more or less vertical position until it comes into contact with a solid object.

Although under natural conditions the cell which is to form a rhizoid, and the direction of growth of the rhizoid, appear to be determined by light and by the direction from which it comes, the fact that spores will divide and form rhizoids both in the dark and under supposedly equal illumination from all sides successively, leaves us with a doubt whether, after all, the point of formation of the rhizoid may not depend on other factors also. Keeping the spores continuously in the dark for forty-eight hours or more is extremely unnatural. The results of such procedure may also be unnatural; they may mislead us as to the natural course of events. Again, cultivating the spores in a dish on a clinostat is an unnatural proceeding, for in nature the illumination is not even approximately equal on all sides in one plane, but is unequal and in many planes successively. And finally, though darkness follows light and light follows darkness only gradually, on the clinostat as well as in nature, it is obvious that a spore in a dish on the clinostat receives the stimulus of light on one side, and as darkness comes on, there can be only weaker and weaker stimuli, and finally none at all on the other sides of the spore. The direction of division of the spore may or may not be determined by this last stimulus of light. According to WINKLER (**20,** p. 302), a three or four-hour exposure to one-sided illumination is necessary to determine the direction of the first division wall in the eggs of Cystoseira. He suggests that perhaps by changing the direction of illumination 90° or 180° about every three hours, we might stop the germination altogether. This I have not tried with Cystoseira, but as the foregoing shows, such is not the case with Dictyopteris spores, for they germinate in darkness, and also on the clinostat, at once, although perhaps not as rapidly as under ordinary illumination. It may take three or four hours under ordinary conditions to determine the line of division of an egg or spore. It may take much less time, much less of a stimulus by light, to determine which of the two cells thus formed shall send out the rhizoid. In

cultures of *Dictyota dichotoma* under one-sided illumination, but with the ordinary alternation of daylight and darkness, I noticed that both the direction of divisions that took place at night and also the cell which put out the rhizoid did not conform to the rule to which those spores which germinated in the daytime evidently pointed. This is clear from *figs. 17* and *18*. Rhizoids, formed during the night on the side which did and will receive more light during the day, bendaway from the light when the daylight comes. In such cultures as these we have much more nearly normal conditions than in continuous darkness or on the clinostat. Divisions often occur and the rhizoids often grow out in darkness, and though the spores were lighted only from one side during the day, the direction of these divisions and the side from which the rhizoid springs follow no rule. This fact at least suggests, but without proof, that influences preceding illumination also affect the direction of division of the spores, and the point of origin of the rhizoids.



FIGS. 17, 18.—*Dictyota dichotoma*. ×123.

17. Germinating spores 1½ days since sowing on ground glass in dish lighted only through vertical slit, direction of light indicated by arrow. Note that spores 1, 2, 3 divided during the night (in darkness), and that the rhizoids of 2 and 3 are curving away from the light.—18. Somewhat older.

It does not seem to me necessary to assume a polarity in the spore. There is no evidence in the form of the undivided spore that there is such a polarity, for the undivided spore is spherical or spheroidal. After the first division the spore becomes ellipsoidal by the growth of the daughter cells at right angles to the division wall. The rhizoids grow from one or the other end—sometimes from both ends—of these ellipses, not from the side; but beyond this there is no indication of the point of origin of the rhizoid. So far as I can see, then, all one is justified in saying is that, in the light, the direction of division of the spore and the point of origin of the rhizoid are determined mainly by the direction from which the light falls upon them, but that the spore has the impulse both to divide and to form a rhizoid, and will do both even in the absence of any directive influence. In the latter case the direction of division and the point of origin of the rhizoid are determined by conditions preceding the escape of the spore from

the mother cells, conditions which may have induced a polarity in the spore, but a polarity which is not so fixed that subsequent influences cannot alter it.

Influence of contact on germinating spores.—From the work in fresh-water algae reported in the foregoing pages, one is led to suspect that the character of the surface with which the rhizoids of germinating spores of marine algae come into contact will largely determine the shape and completeness of attachment of the holdfasts. The strength of the holdfasts as the plants mature is determined not merely by the surface but by other factors. Among these may be mentioned the movement of the water in currents and waves, the size and shape of the plants, and all other factors which affect the strain which the holdfast must withstand.[7] But the first attachment of sessile algae, whether marine or fresh water, is greatly influenced by the roughness of surface. I was first led to suspect this by the extraordinary freedom of Spirogyra and Iridea—the smoothest, most slippery fresh and salt water algae, respectively, which I know—from diatoms and other sessile plants growing upon them. Cladophora and Microcladia, comparatively rough forms, show the direct opposite.

To test this hypothesis with marine algae, I put in the bottoms of the glass dishes used for cultures cover glasses 18×18^{mm} square, which had been carefully ground on one side on a stone. One half of the cover glasses were put smooth side up, the other half rough side up. At first I used the cover glasses only rough side up, letting the smooth glass of the dishes furnish the other surface. This plan seemed open to objection, as the glass of the dishes might not have the same composition as the material of the cover glasses, and the light would not be the same on a ground surface as on a smooth. This latter objection is not wholly eliminated even by using thin cover glasses, but it is as nearly eliminated as at present possible.[8] The

[7] PFEFFER (1, p. 305) has felt obliged to retract his published conclusions, based on the work done in his laboratory by the late R. HEGLER (6), that an increased strain acts as a stimulus to the development of increased strength, as shown in part by anatomical changes in the tissues; but I may venture to express the belief that time will show that PFEFFER and HEGLER and not PFEFFER and BALL (1) were right.

[8] The objection can be and was eliminated in certain cultures by keeping them in the dark. The results were similar to those in the light, but darkness necessarily introduces other effects if prolonged.

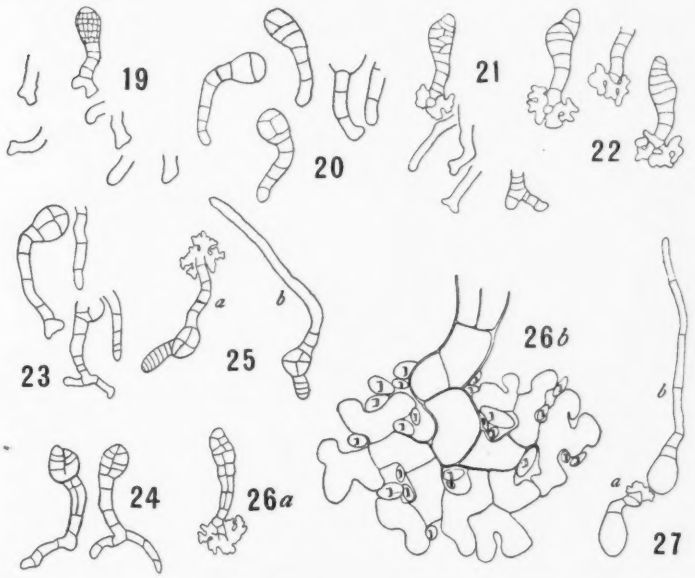
cover glasses ground on one side only, some with the ground surface upward, others with the ground surface downward, served as the bottom on which the spores settled.

In these experiments I used the same species previously enumerated, but those which form a single rhizoid at first give more immediately recognizable results than those which, like Cystoseira, form several rhizoids. For this reason Dictyota, Dictyopteris, and Laurentia are preferable. I shall describe first Dictyopteris, as it was the marine alga with which I first obtained satisfactory results. The results obtained with Laurentia are so similar that I shall not speak of them further.

In *fig. 19* we have sketches of Dictyopteris plantlets two and five-sixths days after sowing on ground glass. *Fig. 20* shows plantlets sowed at the same time on smooth glass. In the first set the rhizoids are beginning to enlarge, and one to branch, at the tips. In the latter there is no such appearance. The idea that this difference in appearance might be due to a difference in age suggests itself. But the difference in age could be only slight, for the fertile branches were removed at the same time from both dishes, and both dishes were emptied and filled with fresh sea water at the same time. Emptying the dishes generally removes the youngest spores, those still unattached or only slightly so, leaving those which are equally firmly attached. I am nevertheless inclined to think that not merely is growth in the part of the rhizoid in contact with a rough surface stimulated by that contact, but also the growth and development of the other parts of the plantlet also. There seems to be a transfer from cell to cell of the stimulus produced by contact, a stimulus the greater the rougher the surface. If this be true, there is every reason for the younger appearance of the plantlets on the smooth glass, for their growth was less stimulated than that of the other plantlets. This is in accord with the observations previously referred to (**10**) which Loeb made upon animals.

Fig. 21 shows the same group of plantlets nearly twenty hours later. Here holdfasts are evidently begun. Twenty hours later than this we have the condition shown in *fig. 22*, where the rhizoids have almost completely lost their filamentous appearance and have become holdfasts, circular in general outline, but with elaborately crenated

margins. Comparing these two figures with *figs. 23, 24,* showing plantlets of the same age on smooth glass, we see that the plantlets have not changed in character from day to day, though they have grown; that the rhizoids are still filamentous; and that no holdfasts are yet begun.



FIGS. 19–26.—*Dictyopteris polypodioides.* ×123, except 26 *b*, ×900.

19. Germinating spores $2\frac{3}{4}$ days since sowing on ground glass.—20. Same in every respect except sown on unground glass. Note that plantlets appear younger than those of same age on ground glass.—21. Same as *fig. 19*, but $3\frac{3}{4}$ days since sowing.—22. Same as *fig. 21*, but 24 hours later, $4\frac{3}{4}$ days since sowing.—23. Same as *fig. 20*, $3\frac{3}{4}$ days since sowing.—24. Same as *fig. 23*, 24 hours later, $4\frac{3}{4}$ days since sowing.—25. Ten days since sowing, *a* on ground side of cover glass, *b* on unground side, in sea water.—26*a*. On unground cover glass.—26*b*. Same showing diatoms and diatom-shells, *D*, in almost every lobe of the well-developed holdfast.

FIG. 27.—Two *Dictyota* plantlets on smooth glass. ×123.

a has formed a holdfast on coming into contact with dirt; *b* finding no such obstacle has grown out into a long rhizoid; *a* erect, *b* erect at tip but rhizoid creeping.

In *fig. 25* we see the condition of two plantlets of Dictyopteris ten days after sowing, the one on ground glass, the other on smooth. These are not the extremes of two series of plants, but are the average. On unground glass, however, under certain conditions, as elaborate

holdfasts may develop as on ground glass. When I saw the plant shown in *fig. 26a*, I thought my hypothesis was disproved, for here we have as elaborate a holdfast as on ground glass. On examining the plant with a stronger magnification, I found, as *fig. 26b* shows, that diatoms or diatom-shells were very numerous on the glass at this point, making it rough, or rather covering it with obstructions to the growth of the base of the plantlet. This plant and the many others like it confirm my belief that roughness of surface stimulates the sessile algae firmly to attach themselves.

It must be noted, however, that ground cover glasses kept in cultures for a week or so become slimy; their roughness is reduced or concealed by a thin, very smooth coat, which must be dissolved off before one can use the cover glasses again with the maximum effect. Even when all "dirt" and diatoms are washed off, the cover glasses are not clean as they are when new; they must have the slimy coat removed too. This is easily done by boiling in fresh water for a few moments. On the other hand, diatoms, animal excrement, and fine dirt generally, often so roughen the unground surface of glass as to induce holdfast formation of marked character.

When for any reason, such as the extreme smoothness of the glass, or the absence of any contact whatever, the elongation of the rhizoids is not stopped, they may attain surprising lengths and often in a very short time. *Fig. 25* shows such an extraordinarily long rhizoid of Dictyopteris. *Fig. 27* shows us two plantlets of *Dictyota dichotoma* growing on the same smooth side of a cover glass. In the one case, the rhizoid soon came into contact with small particles of dirt sticking to the glass, and thereupon ceasing to grow in length, formed a typical holdfast. In the other case, no dirt caught the rhizoid, which continued to grow over the smooth slime-covered glass.

I may here say something about the amount and the rate of growth of these germinating spores. On November 5th, at a quarter past twelve, I made a camera drawing of a spore of *Dictyota dichotoma*. Four hours later I similarly drew the same spore. And the next morning at a quarter to eleven o'clock I made another drawing. This third drawing is 107 per cent. longer than the first and 85 per cent. longer than the second. Another spore was 0.089^{mm} long when the first drawing was made. In four hours it grew 0.016^{mm}; in twenty-

two hours and a half it grew 0.089^{mm}; and in forty-five hours and a quarter it grew 0.2195^{mm}. These figures converted into rates of growth per hour show that the plantlet increased in length at the rate of 4.23 per cent. per hour for the first four hours, 4.4 per cent. per hour for the next eighteen hours, and 5.82 per cent. per hour for the following twenty-three hours. These figures, however, distribute the growth over the whole length of the young plant, whereas it is mostly at the tip. Since this is the case, the rate of growth in the growing part must be much higher. I was not able at the time to make measurements to ascertain this rate in Dictyota. Similarly a spore of *Dictyopteris polypodioides* increased in length 360 per cent. in three days, or an actual increase in length of 0.292^{mm}.

All of these cases of growth are unusual. The plantlets sent out their rhizoids either horizontally or somewhat obliquely upwards, at all events without contact with the surface of the glass. Where contact occurs, there is no such extraordinary growth unless the contact be with an exceedingly smooth slippery object. There, as in water, the rhizoid will continue to elongate.

In a spore of Dictyopteris I attempted to measure the length of the growing region, the total increase in length, and the distribution of this increase among the cells of the rhizoid; but the growth rate in this instance has little value, because of the extraordinarily cold weather prevailing at the time. As the laboratory is cold at night, the growth rate for twelve hours of the twenty-four must have been much below normal. However, I will give the figures. The increase in length of the tip cell of the rhizoid was 150 per cent. or 0.078^{mm} in twenty-four hours. The increase in length of the cell next behind was 40 per cent. or 0.020^{mm}. The other cells of the rhizoid did not lengthen at all. Of the total increase in length 79 per cent. was made by the tip cell. This cell had at the outset only 41 per cent. of the length of the growing region. The actual zone of growth, however, is only the tip of the cell. Hence these percentages give only a vague and quite inadequate idea of how rapid the growth is in the actually growing part.

SUMMARY.

1. The zoospores of Oedogonium, as has long been known, are sensitive to light, the direction of locomotion and the place at which they come to rest being determined much more by the direction and

the intensity of the light falling upon a body of water than by other influences, such as unequal distribution of oxygen, etc.

2. Apparently the germination of the zoospores of sessile algae is induced primarily by interference with their locomotion. When this is blocked, germination begins; conversely, when nothing prevents locomotion, they do not germinate.

3. The nature of the attachment formed by the germinating zoospores of sessile algae is dependent upon the roughness of the surface of the object with which they come into contact. Upon extremely smooth surfaces—such as the surface of clean water and clean wet gelatine—the spores form either only the shortest most rudimentary holdfasts or merely rhizoids; whereas, on relatively rough surfaces, the holdfasts are large and conform in their lobing to the contour of the surface. Furthermore, ordinarily floating algae may sometimes be induced to form rhizoids or other organs of attachment if brought into contact with sufficiently rough surfaces.

4. The discharge of the spores or gametes of Dictyopteris, Dictyota, and Cystoseira is strongly influenced by light, the discharge being much more rapid within a few hours after exposure to light than before or than in continuous darkness. For this reason the time of the discharge as well as the rate is strongly influenced by light, and a periodicity of discharge is established which follows approximately the periodicity of daylight and darkness.

5. The spores of the sessile marine algae studied germinate better in normally alternating daylight and darkness than in continuous darkness; and subsequent growth and development follow the same rule.

6. As shown by WINKLER to be the case with *Cystoseira barbata*, we have found that the direction in which the light falls determines the plane of the first division in the germinating spores of *Cystoseira erica marina*, Dictyopteris, and of Dictyota, the new cell wall being formed at right angles to the incident rays.

7. Similarly, the rhizoids or holdfasts formed by germinating spores ordinarily issue from the daughter cells away from the light. In darkness the rhizoids arise in all possible directions, sometimes even from both cells of a germinating spore.

8. The direction of growth of rhizoid and of plantlet is determined

mainly by the direction from which the light comes: the rhizoids are negatively phototropic, the plants positively.

9. As in fresh-water algae, so also in sessile marine algae, the nature of the surface with which the spores come into contact very largely controls the nature of the attachment formed, a rough surface inducing the growth of a large and well-developed holdfast, a smooth surface causing proportionately less growth.

10. Though the direction toward which the rhizoids ordinarily grow is determined at first by light, the character of the surface with which the rhizoid comes into contact still more strongly influences the direction of its growth.

11. The direction, rate, and kind of growth of these germinating spores is strongly influenced by contact irritation.

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THE BOGS AND BOG FLORA OF THE HURON RIVER VALLEY.

EDGAR NELSON TRANSEAU.

(WITH SIXTEEN FIGURES)

I. The Huron River valley.

PHYSIOGRAPHIC FEATURES.

THE Huron River valley, to the botanical survey of which the present paper forms the sixth contribution, is located in the southeastern part of Michigan. As indicated in *fig. 1*, the valley embraces parts of five counties.

Throughout, its surface forms are of glacial origin and, with the exception of the immediate borders of the river, have undergone but slight modification since glacial times. Perhaps its most striking topographic features are the rough morainic hills of its upper and middle courses, and the gently undulating plain of its lower course.

The river has its source in west-central Oakland County in Big Lake, 9 miles (14.5^{km}) southeast of Holly and approximately 40 miles (64^{km}) northwest of Detroit. Starting with an elevation of 950 feet (290^{m}), after a course, extending for 50 miles (80^{km}) generally southwestward and then for another 50 miles (80^{km}) southeastward, it empties into Lake Erie at an altitude of 573 feet (175^{m}) above tide. As is common in areas of glacial deposition, the topography of the drainage basin of the Huron has little of the appearance usually suggested by the term "valley." The upper two-thirds of its course is a winding depression among morainic knobs, lake basins, abandoned glacial drainage channels, and sand plains. Here the river is characterized by long reaches and occasional slight riffles. At intervals it broadens into stretches of lake-like character, as is illustrated by such bodies of water as Commerce, Taylor, Strawberry, Whitewood, and Bass Lakes, each with an area of one-fourth to one-half a square mile (65–130 hectares). The river margin is usually low and swampy.

Its tributaries enter it at every angle, and bring to it the drainage of hundreds of lakes and swamps. Most of these lakes are small,

occupying areas of an acre (half a hectare) or more, but there are several of considerable size. Portage and Whitmore[1] Lakes occupy one and one-fourth to one and one-half square miles (325–390 hectares), while Union, Straits, Four-Mile, Ore, Independence, etc.,

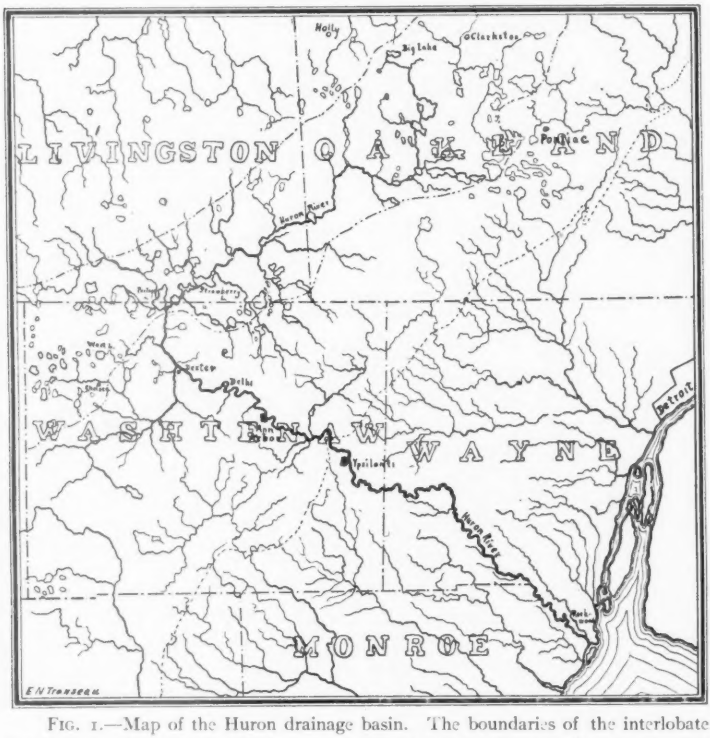


FIG. 1.—Map of the Huron drainage basin. The boundaries of the interlobate moraine are shown by the lines —·—. The boundary between the clay morainic belt and the lake plain is marked by the line - - - - -.

cover a fourth to half a square mile (65–130 hectares). A very large percentage of the tributaries lie in flat-bottomed depressions whose surface approximates the ground-water level, consequently producing thousands of acres of swamp and marsh land. Everywhere occur small undrained depressions, some well above the average ground-water level, others containing lakes and bogs. It is also worthy of

[1] Not connected with the Huron River by surface drainage.

note that a large part of the surface drained by the Huron and its tributaries, before it makes the great bend to the southeast below Portage lake, is made up of sand and gravel, composing and accompanying the Saginaw-Erie interlobate moraine. It is a region of steep hills, with occasional dry plains, everywhere penetrated by lakes and swamps.

The country which the river next crosses, beyond the great bend, for a distance of 20 miles (32^{km}) is composed of glacial till plains and clay moraines—a belt extending NE–SW, approximately parallel to the interlobate moraine. Here, although the hills are well marked, the slopes are more gradual and the basins broader. The river is bordered by banks several feet in height, and seldom attains a width of 150 feet (50^{m}).

The last 30 miles (50^{km}) of the Huron River traverses a meandering course sunken from 50 feet (15^{m}) at Ypsilanti to 25 feet (7.5^{m}) at Rockwood below the surface of a glacial lake plain sloping gently southeastward from the morainic belt just described, to the western shore of Lake Erie. The soil is here composed of sand, sandy loam, and—in the vicinity of the lake—clay; the only topographic features aside from the sunken water courses being the several beach ridges and dunes marking the successive stages in the lowering of the glacial lakes, forerunners of the present Lake Erie.

There are, then, three natural divisions of the Huron drainage basin: (1) the loose-textured rough interlobate moraine; (2) the clay morainic belt lying to the southeast of it; (3) and the low-lying plain extending to Lake Erie. Each implies important differences in the way of bog formation and provides edaphic factors which determine to a large extent the nature of the dominant forest covering.

PHYSIOGRAPHIC HISTORY.

The history of these topographic features is for the most part bound up with the retreat of the ice at the close of the last (Wisconsin) glacial epoch. A topographic map of the region lying between Lakes Michigan and Erie shows that the morainic hills so characteristic of the Huron basin are part of a belt of similar physiography extending from northern Indiana well up into the "thumb" of lower Michigan (*fig. 2*). This belt of glacial deposits is directly connected with the

development of reentrant angles along its crest, as the great continental ice sheet[2] became more and more differentiated into lobes during its retreat (**52, 13**). In northern Indiana it marks the first areas uncovered, as the mass of ice, pushed forward from the basin of Lake Michigan, separated from that originating in the Lake Huron and Lake Erie basins.

When the Huron River basin was reached, the Saginaw lobe had been developed and lay over the northwestern part, while the Huron-Erie lobe covered all of the territory southeast of the interlobate

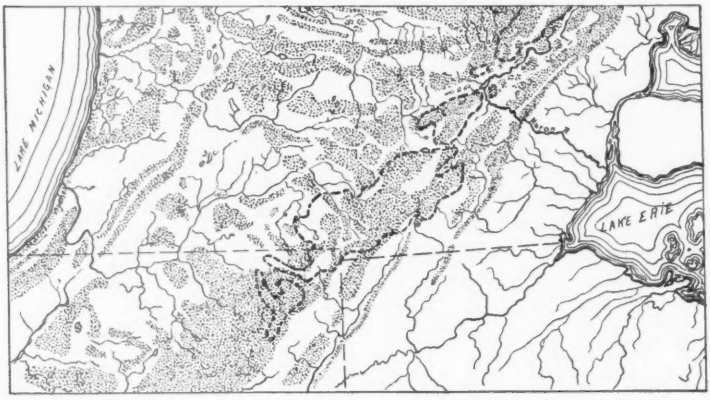


FIG. 2.—Map of southern Michigan, northern Indiana, and northern Ohio, showing "moraines with strong expression." After LEVERETT, U. S. Geol. Surv. Mon. 41, *plate 2*. The irregular dotted lines mark the 1000-foot (300m) contour.

moraine. The first portion of our area to be uncovered is the triangular gravel outwash apron extending southwestward from Sugarloaf Knob. This was the beginning of the Huron River. Kavanaugh Lake then lay just under the edge of the Erie ice, and Crooked Lake occupied a similar position on the southern border of the Saginaw lobe. As has been recently determined by Mr. FRANK LEVERETT, of the U. S. Geological Survey, the subsequent history of the Huron drainage is most remarkable.

The waters from the glacial drainage at first flowed generally westward, reaching the Kalamazoo River near Albion, thence to the St. Joseph at Three Rivers. At South Bend, Indiana, it crossed

[2] For general map see no. **55**, p. 411. (Bibliography at close of this paper.)

to the Kankakee River, and reached the Mississippi by way of the Illinois.

As the reentrant extended itself further to the northeast, another channel was opened for the Huron drainage westward past Pinckney into the Grand River, and from there to Battle Creek and the Kalamazoo River. Below the city of Kalamazoo it cut across to the Paw Paw River, and reached the Mississippi by way of Lake Chicago.

When the ice of the Erie lobe had retreated as far eastward as Ann Arbor, and all of the interlobate moraine had been uncovered, a third outlet for the waters of the Huron was opened by way of Clinton and the Raisin River, which at that time emptied into glacial Lake Maumee at Adrian (**32,** *pl. 20*). This lake was drained by the Wabash River into the Mississippi.

As soon as the ice margin passed the clay morainic belt already described, the Huron reached Lake Maumee at Ypsilanti by way of its present channel. But Lake Maumee had meanwhile changed its outlet to the northward, its drainage going by way of Imlay (**53**) to the Grand River, Lake Chicago, and the Mississippi (**32,** *pls. 21, 23, 26*).

Later the Erie basin was entirely freed of ice, and its water for the first time flowed eastward into the Ontario basin (glacial Lake Iroquois), and thence by way of the Mohawk to the Hudson. With the clearing of the St. Lawrence channel the present system was inaugurated.

Aside from the physiographic interest connected with their early history, these glacial drainage channels are of distinct biological interest. They furnish continuous lowland habitats extending in all directions. In so far as they are represented by broad, open valleys, and connect with tributaries of the northern Ohio valley, they provide important highways for the dispersal of southern river-valley species.

FORESTS.

The three topographic divisions already described exhibit marked differences in their forest aspect. On the lake plain we find the richest and most mesophytic of the forest types. This lowland habitat is a continuation of the northern Wabash valley, and it is not surprising that its flora should be of much the same character. Here

we find the greatest variety of tree species, among which are *Fagus atropurpureus*, *Quercus rubra*, *Ulmus americana*, *Platanus occidentalis*, *Acer saccharum*, *Tilia americana*, *Acer saccharinum*, *Fraxinus americana*, *Gleditsia triacanthos*, *Liriodendron tulipifera*, *Gymnocladus dioica*, *Cercis canadensis*, *Asimina triloba*, and *Celtis occidentalis*.

The clay morainic area is dominated by *Quercus rubra*, *Q. alba*, *Q. velutina*, *Hicoria ovata*, *H. glabra*, *Acer rubrum*, *Ulmus americana*, and *Quercus macrocarpa*.

In the region of the interlobate moraine the disappearance of the more mesophytic forms is quite marked. The forest is there largely composed of *Quercus coccinea*, *Q. macrocarpa*, *Q. velutina*, *Q. alba;* and as we go northeastward these become associated with *Pinus strobus*. *Quercus prinoides* forms a characteristic shrubby growth along the roadsides and in waste places.

Such is the forest background in which are set the thousands of acres of bog and swamp, and to which the groves of *Larix laricina* exhibit a marked contrast. These tamarack areas are to be seen on all sides in the region of the interlobate moraine; they are quite common in the clay morainic belt, but are practically wanting on the lake plain.

As one follows along the morainic country from northern Indiana into the "thumb"of Michigan, he passes from a region dominated by a rich mesophytic broad-leaved forest to one of conifer and xerophytic broad-leaved ascendency; from a region whose low grounds are characterized by a swamp flora to one in whose depressions the bog flora reaches a high state of development. In this connection it is interesting to note that one finds this gradual change epitomized in the Huron valley as he goes from its mouth to its source.

METEOROLOGICAL CONDITIONS.

Under this head we shall consider the general meteorological conditions of the Huron basin, and compare them with the meteorological conditions found about the center of the distribution of bog plants (**55**, p. 406). In general, this center extends from Lake Winnipeg through the upper Great Lake region down the valley of the St. Lawrence to the Atlantic coast. It is in the coast provinces, however, that the bogs reach their highest development, in the form

of the "raised bog." Certain temperature phenomena associated with the bog habitat will be discussed in connection with the analysis of the life conditions obtaining in bogs.

Rainfall.—In the following table is given the mean monthly and annual precipitation for seven stations located within or near the Huron basin. As their individual variation is but small, it is probable that the average for the stations gives a fair estimate of the rainfall and its distribution. Appended are the corresponding records for the maritime region of eastern Canada:

MEAN PRECIPITATION IN INCHES.

Station	Alt. feet a.t.	Record for Yrs.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
Ann Arbor.	930	23	1.90	2.10	2.12	2.88	3.72	3.30	2.82	2.45	2.58	2.82	2.77	2.35	32.08
Ypsilanti..	736	18	1.97	2.61	2.48	2.24	3.08	4.02	3.09	2.24	2.63	2.70	3.29	2.32	33.60
Jackson...	927	6	2.06	2.21	3.14	1.26	3.22	3.02	2.47	1.76	1.74	3.61	2.87	1.56	28.02
Annpere...	924	11	1.98	2.19	2.42	2.60	3.38	2.44	2.66	2.85	1.93	2.04	2.64	1.77	26.05
Ball Mt....	932	13	1.73	1.76	2.07	2.12	3.52	3.13	2.47	2.50	2.62	2.69	2.71	2.30	29.72
Birm'gham	860	15	1.91	2.00	2.32	2.53	3.36	3.15	2.56	2.38	2.33	2.51	3.02	1.88	29.95
Average.			1.94	2.16	2.42	2.27	3.53	3.10	2.68	2.38	2.30	2.73	2.88	2.03	30.22
St. John, N. B.(18)		?	5.55	3.93	3.80	2.50	3.66	2.72	3.29	4.64	3.08	4.13	4.71	5.16	47.17
Halifax, N. S.(51)		22	5.63	4.94	5.15	4.00	4.43	3.68	3.43	3.96	3.53	5.21	5.26	5.52	57.74

It will be noticed from the above data that the precipitation is quite evenly distributed throughout the year. It reaches its maximum during the months of May and June, when the vegetative processes of the bog plants are most active. It approaches its summer minimum during July and August, when the temperature commonly attains its greatest height. The former implies that the water level in the bogs is kept at or above the surface of the substratum for weeks at a time. The latter involves strong transpiration on the part of the vegetation, when the water supply must be drawn for the most part from the substratum. The average number of rainy days during the past five years is one hundred per annum.

The average snowfall in this region during the five years, 1898 to 1902, amounts to 38.4 inches (975 ^{mm}). In the case of the bogs this thickness is usually increased by the drifting of snow from the surrounding hills. Observations during the past two winters show that the bogs are covered by ice to a thickness of a foot (30 ^{cm}) or more.

Consequently, low shrubs, and herbs which pass the winter by means of underground stems, are well protected from low temperatures and sudden temperature changes. The ice further results in lowering the temperature in spring and in retarding the beginning of favorable growth conditions.

The percentage of sunshine is not published by the several stations, but the number of clear and partly cloudy days is stated. The numbers from the various stations show marked differences, due to different standards established by the observers; but perhaps these are largely eliminated in the average. If we take the average number of clear days, add to it one-half the number of partly cloudy days, and divide by the number of days in a year, we obtain a percentage of forty-six. This probably approximates the percentage of sunshine.

In comparison with the rainfall data for Halifax and St. John, it is notable that in the latter localities the mean rainfall, both monthly and annual, is considerably larger. The annual precipitation exceeds that of the Huron valley by fully 20 inches (50 cm), or about 40 per cent. Finally, the sunshine percentage is slightly lower, being 39 for Halifax and 42 for St. John.

Temperature.—The following table exhibits the monthly and annual means for the several stations already cited:

MEAN TEMPERATURE IN °F.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
Ann Arbor	22.2	23.1	30.6	45.4	53.2	67.3	72.0	69.3	62.5	49.9	36.4	27.1	46.6
Ypsilanti	25.9	24.2	32.3	46.7	58.1	63.5	71.1	69.7	61.8	49.9	36.7	27.6	47.3
Jackson	26.1	20.3	32.7	47.5	59.4	69.4	74.8	71.8	64.8	54.7	37.7	26.5	48.8
Annpere	24.7	21.7	31.3	50.2	56.5	68.4	71.8	67.6	63.0	49.8	35.9	26.7	47.4
Ball Mt.	22.6	21.4	27.6	45.3	56.0	66.9	70.0	68.1	62.2	49.5	35.9	27.1	46.0
Birmingham	23.1	22.8	30.4	46.5	57.3	69.1	72.2	68.4	61.5	49.7	36.7	27.0	47.1
Average	24.1	22.2	30.8	46.9	56.7	67.1	71.9	69.1	62.6	50.6	36.5	27.0	47.2
St. John, N. B.	18.6	18.7	26.3	38.6	48.8	56.3	61.0	61.3	55.6	44.7	36.1	23.7	40.8
Halifax, N. S.	22.0	22.7	28.7	38.2	48.7	57.6	64.2	64.8	58.2	48.0	38.2	27.0	43.2

The table shows that the temperature conditions are comparatively uniform throughout the basin. The maximum average temperatures occur in July and August. But the significance of the data becomes more apparent, in so far as the bog vegetation is concerned, when they are compared with those of St. John and Halifax (*fig. 3*). It is to be noted that, although the average temperature for June,

July, and August of the Huron basin is 8.6° F. (4.8° C.) higher, its rainfall during the same period is less by 2.6 inches (66 mm). There can be little doubt as to the effect of such differences upon the growth of the bog species, especially the sphagnum whose moisture supply is more directly dependent upon atmospheric water than upon the

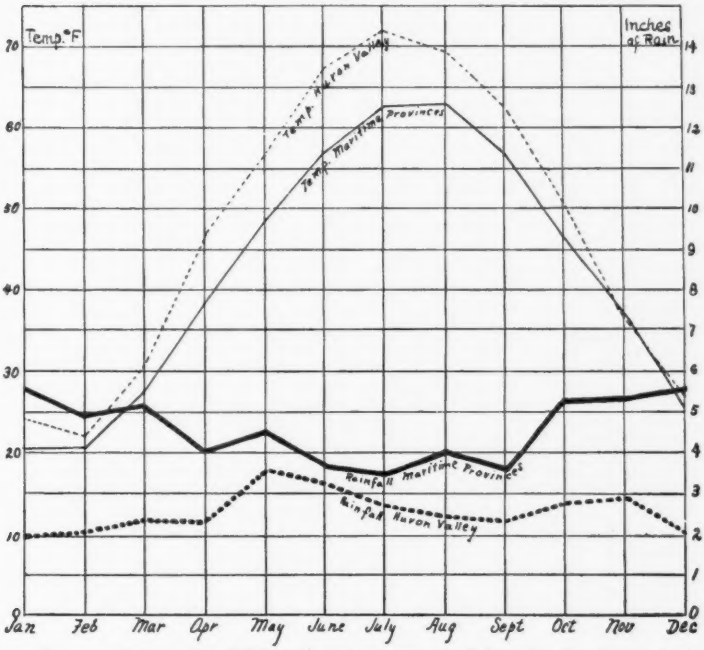


FIG. 3.—Curves of rainfall and temperature conditions in the Huron basin compared with those of the maritime region of Canada.

soil solution. Again, the occurrence of high temperature with decreased precipitation means the production of conditions impossible for the development of the "raised bog," if not unfavorable to the highest development of the "flat bog."

Since bogs attain their maximum development in a region of great rainfall and comparatively low temperatures, it is reasonable to infer that the extremes of summer heat become peculiarly significant in this region. Examination of the weather records shows that

temperatures of 97–100° F. (36–38° C.) are likely to occur every year, and that temperatures approximating these may be prevalent for several days in succession each season. When these extremes coincide with periods of drought, they must act as important checks on the growth of the bog plants, especially the sphagnum. As we pass from northern Indiana along the moraine into Michigan, the gradual increase of bog development, of the variety of bog species, and of the areas covered by sphagnum is very marked. Although other factors are involved, this increase may be correlated with a decrease in summer temperature extremes.

II. The bogs: their development and ecological conditions.

PHYSIOGRAPHIC ORIGIN OF THE LAKE AND BOG BASINS.

In connection with the special consideration of the bog flora, it is of interest to note the origin of the depressions in which this flora has developed and flourished. Indeed, in the morainic belt of the Huron basin it would seem that among the agencies which have produced important topographic changes since glacial times, the bog plants stand near the head of the list. Stream erosion and deposition have been slight, while lake basins have been filled and the level of depressions generally raised by the deposition of plant débris.

As no attempt has as yet been made at the mapping of peat deposits and muck soils, no reliable estimate of the total amount of aggradation accomplished by plant agencies can be made. Yet the frequency with which in field work one encounters peat soils, in various stages of making or decay, suggests that in the aggregate such deposition has been most effective in this region. The northwest quarter of the Ann Arbor topographic map, which embraces an area of about 215 square miles (55,700 hectares), located in the morainic portion of this basin, indicates approximately 43 square miles (11,500 hectares)—20 per cent.—as swamp land. It is probable that at an early time this area was very much larger, but with the settlement of the land many extensive areas have been drained and only the dark humous soil remains to suggest its past history.

The most frequent source of lake and bog basins is here found in connection with the deposits made by glacial drainage. Among the vicissitudes attending the retreat of a glacier are the occasional

detachment of blocks and masses of ice through differential melting (**19**). If these detached masses happened to be in the line of the overloaded glacial drainage, they became covered to a greater or less extent by sand and gravel. Owing to the poor conduction of heat by such deposits, they melted with extreme slowness. Where this latter process was prolonged until the drainage line had been abandoned or the stream had ceased depositing, subsequent melting brought about a settling of the deposits and the production of basins. Sister, Kavanaugh, and Crooked Lakes are examples of this type.

In the case of the chain of lakes which form a part of the Huron River in northwestern Washtenaw County, and such lakes as Portage, Tamarack, Ore, and Bass, according to LEVERETT, there was an additional settling of the fluvio-glacial deposit itself. This latter process has been of the greatest importance in the development of extensive bog areas. In the Portage Lake region this settling has amounted to as much as 40 feet (12 m) in certain places, and has resulted in reducing many hundreds of acres of land to the ground water level.

Throughout the belt of till plains occur shallow marshes, sometimes drained, but usually by a sluggish meandering stream, itself impeded by the growth of swamp plants. These basins are the natural expression of the unequal deposition of glacial material. Till plains result from a comparatively rapid retreat of the ice; hence the depressions are usually shallow, and have been mostly filled with peat to the level of the present drainage. The several small lakes lying to the west of Dexter are examples of basins not yet obliterated.

Where the retreat of the glacier is slow and deposits are made to a great thickness about the edge of the ice, kame or "knob and kettle" topography results. The basins of such areas are characterized usually by high margins and comparatively steep slopes. West, Silver, North, Island, and South Lakes may be cited as examples.

As we know from remains discovered in peat deposits, among the animals inhabiting this region in early postglacial times were the mammoth, mastodon, bison, peccary (*Platygonus compressus* LeConte) (**57**), elk, and "big beaver" (*Castoroides ohioensis* Foster). The last named is not a beaver (**34**, p. 256), but is more nearly related to the Coypu rat of South America. The common beaver

(*Castor canadensis* Kuhl) has been an important factor in the creation of bog areas (**37**), and in the extension of areas already existing, by the building of dams. The beaver was found in this section when it was first settled, but the last known specimen was killed sixty-nine years ago. The occurrence of peat deposits several feet in thickness and covering quite large areas, bordering streams, whose channels lie deeply sunken in the deposits, seems to find its best explanation in this manner. But little field work has been done on the relation of beavers to the peat deposits, and examples are still too hypothetical to cite in this connection.

BOG AND LAKE VEGETATION.

Of the plants which might come into a new land area containing basins, such as was laid bare on the retreat of the glaciers, none is better adapted to rapid migration than the group of aquatic plants. Whether we have in mind the smaller submerged varieties or the partially submerged littoral species, their wide geographic distribution and uniform associations bespeak their evident solution of the problems of dispersal. The fact that deposits of peat and marl have been found in northern Indiana and lower Michigan to a thickness of 40 feet (12 m) would indicate that in these particular basins the vegetation must have obtained an early foothold.

Concerning the deposition of marl, it is of interest to us only in so far as it becomes an agent of aggradation in the basins. In the reports (**5, 42, 21**) on the marl deposits of Indiana and Michigan, many examples are cited where the marl forms the underlying substratum of peat deposits. That its deposition to a large extent is due to plant life has been shown by DAVIS (**9, 10**). The plants most concerned with this process are the Characeae and Cyanophyceae (Schizothrix, Zonotrichia). They are probably aided by certain mollusks, and perhaps also by chemical precipitation. As for the Characeae and Cyanophyceae, they have a wide range of habitat in different lakes, and may occur in deep or shallow water and on various rock substrata. Where they come into competition with shore species, the rank growth of the latter usually precludes their existence in sufficient amount to be of importance in marl formation. Where wave action is strong, the chara is confined to deeper water,

but the blue-green algae may be present up to the water's edge, in such situations frequently forming marl pebbles. The lower limit of existence is largely determined by the transparency of the water, and may lie between 20 and 30 feet (6–9^{m}). Of the littoral plant associations there are commonly two quite distinct divisions, the outer made up largely of submerged or floating pondweeds and water-lilies, the inner of half-submerged rushes and sedges. Both are concerned in the process of peat formation. Under such conditions there naturally develop, in regions of calcareous underground waters, an outer zone of chara dominance and marl deposition, and an inner zone of pondweed-sedge dominance and peat deposition. Variations in the slope of the bottom, in the amount of wave action, in the presence of shore currents, and in the color of the water, determine whether one or both of these processes shall go on, and to what extent these activities are kept distinct or grade into one another.

In the case of the peat, however, the process is not dependent upon water species alone. They act merely as forerunners of a denser and more luxuriant vegetation which frequently is of greater quantitative importance. Briefly, we may note here that in the case of the bogs, unlike that of the swamps, the plants which develop on the margin, especially *Carex filiformis* and forms of Eriophorum, are able to secure all of their food materials from the water and air and build their own substratum. This tangle of roots and rhizomes usually attains a thickness of several inches, and on account of its low specific gravity floats on the surface of the water. Upon this foundation the sphagnum and bog shrubs advance, adding their quota to the débris. Later, these are followed by such tree forms as the tamarack. Coincident with this increased weight and augmented rate of deposition, comes the progressive submergence of the floating substratum, and its gradual disintegration and humification. The accompanying *fig. 4* will serve to illustrate this process.

Within the last two years much has been promised toward the utilization of the peat deposits in this region for fuel purposes. Companies have been organized, and the machinery necessary for the drying and consolidating of the peat has been much improved. At Capac and Chelsea, factories have been erected, and attempts are being made to place the industry on an economic basis. If these

ventures prove successful, we may hope for an interesting body of scientific information to come from the study of bog sections. The work of ANDERSON, LAGERHEIM, SERNANDER, WEBER, and others in Sweden and Germany, gives indication of the data concerning postglacial migrations of plants and animals, and climatic changes, which will be obtainable when our bog deposits become of economic importance.

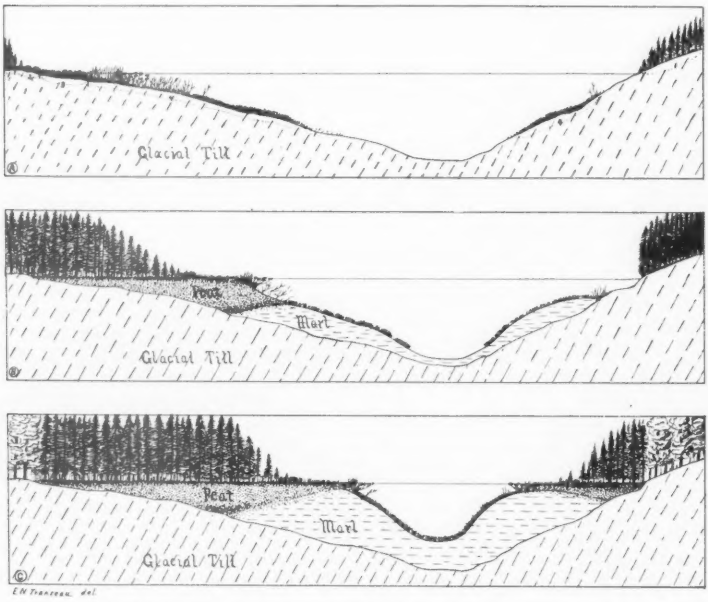


FIG. 4.—Diagrams illustrating three stages in the development of peat and mar deposits in lake basins. In drawing the figures it has been assumed that the rates of marl and peat deposition are approximately equal. The peat accumulates most rapidly on the western side of the basin. On the east side a common effect of wave action is illustrated. The process of peat formation is hindered, while that of marl deposition goes on until the aggradation of the bottom reduces the force of the waves sufficiently to allow the bog plants a foothold. *A* represents conditions in early postglacial times when these basins acquired their first flora. The several plant societies represented are (1) conifer (2) bog shrub, (3) bog sedge, (4) aquatic, the outermost division of which is the chara association. In *B* the conditions for the growth of plants belonging to the northeastern conifer forest formation have reached their optimum. *C* represents present conditions in southern Michigan. The plants belonging to the southeastern broad-leaved forest formation, being climatically favored, occupy the areas of mineral soils, while the conifers are almost restricted to bog areas.

THE GEOGRAPHIC DISTRIBUTION OF PEAT DEPOSITS.

In North America the distribution of recent peat deposits may be conveniently summarized under two heads, genetically unrelated: (1) those of glaciated regions; (2) those of the coastal plain.

The peat of the glaciated area constitutes the great bulk of these American deposits. The southern boundary of this region is marked by a line passing westward from central New Jersey through northern Pennsylvania and Ohio, central Indiana and Illinois, thence northward through southern Wisconsin, northwestward to the Minnesota valley and the Red River of the North in Manitoba, westward through northern Assiniboia and southern Alberta to the Rockies. Here the boundary is deflected southward into Montana, but in crossing toward the coast it is again carried northward into British Columbia, and finally southward among the Cascades of Washington to the Pacific Ocean.

Along this southern border the peat deposits are exceedingly scattered and make up a small fraction of the total land surface. They have accumulated under water in depressions among the recessional moraines. As we go northward, the relative proportion of peat bogs and peat deposits regularly increases, and there is a notable tendency toward the accumulation of pure humus in situations other than depressions containing water. When the tundra or "barren ground" is reached, the accumulation of humus is almost universal. The contrast with our own region is well brought out in RUSSELL'S account of the tundra (**43**, p. 129). The vegetation

> grows rapidly during the long, hot, summer days, dies below and partially decays, but becomes frozen and has its complete destruction arrested, while the dense mat of roots and stems continues to thrive. In this way an accumulation of partially decayed vegetable matter is formed, which increases in thickness from year to year by additions to its surface. The process is similar to that by which peat bogs are formed in temperate latitudes, except that the partially decomposed vegetation becomes solidly frozen. It is in reality an example of cold storage on a grand scale.
>
> Under existing climatic conditions there does not seem to be any limit to the depth such deposits may attain. The amount of carbonaceous material already accumulated in the tundras of America and Asia must equal that of the most extensive coal field known.

South of the boundary above described, peat deposits of consider-

able extent are occasionally met with. In the region of the great plains they are sometimes found beneath a surface covering of sand and wind-blown deposits. TODD (**54**, p. 121) has mentioned the occurrence of such peat deposits in eastern South Dakota. BARBOUR also reports such deposits from central and eastern Nebraska (**2**). On the basis of their field relations and certain fossils which they contain, they are believed to be of Glacial and early Pleistocene age. If the plant materials of these deposits could be carefully worked over with reference to their successive floras, we might hope for some new light on glacial climate, since a part of the deposits are beyond the margin of the Wisconsin ice sheet. But even their location and existence give evidence of climatic change, and plant and animal migration. Although now widely separated from the region of active bog formation, they are historically connected with this division.

Among the mountains of both the eastern and western United States, bogs and swamps are to be found in association with mountain lakes. More frequently than otherwise these depressions are connected with former local glaciation, perhaps the most frequent situations being those afforded by the damming back of water by terminal and lateral moraines. Basins for peat accumulation are also found in solid rock made by glacial erosion. The conditions here are quite similar to those of the north, the altitude bringing about the same general effect as the latitude. The analogy is still further shown on mountains in moist regions where alpine meadows are strongly developed. Not only are the plants related to those of the tundra, but the deposition of peat or humus is again irrespective of basins.

In many places east of the great plains there is another type of situation not directly connected with glaciation, but in which vegetable débris may accumulate to considerable thickness, viz., about the débouchure of cold springs. Toward the north these springs may bring about humus accumulation on slopes, but further south peat is usually associated with pools and small lakes.

The second group of situations in which peat accumulation takes place on a grand scale, are those associated with coastal plain phenomena, such as the rising and sinking of the land, the irregular deposition of alluvial materials in deltas, and the extension of the

land through reef building. These swamps have been described by SHALER, KEARNEY, JULIEN, and others (**46, 26, 24, 7**). They reach their greatest development in eastern Virginia, North Carolina, Florida, and the Mississippi floodplain. They may contain either salt or fresh water, and their vegetation is noted for its density and luxuriance.

The geographical distribution of peat deposits is of interest in this connection because it points to certain factors which contribute to the preservation of humus materials. Certainly in arctic latitudes the most significant factor is the low temperature, for humus accumulates to great thickness even with a scant vegetation. In the northern states and southern provinces of Canada, peat is associated with basins containing stagnant water or cold springs. The annual increment from the vegetation is greatly increased over that of the tundra. Mild temperatures and stagnant waters combine to preserve the plant débris. When we come to the coastal plain swamps of the southern states, this process takes place only where a luxuriant vegetation is combined with areas of stagnant water of considerable depth.

To put it sharply, we may say that, in spite of the scant vegetation, the cold of the tundra results in peat accumulation. In temperate latitudes, mild temperatures and stagnant water combine to prevent the complete disintegration of a vigorous vegetation. In the south, in spite of the high temperature, the luxuriance of the vegetation and stagnant water unite to make peat formation possible.

THE PROCESSES INVOLVED IN PEAT FORMATION.

When for any reason the living protoplasm in a plant or any of its organs is brought to the condition of death rigor, the continuance of this state for a prolonged period inaugurates certain chemical and physical processes which result in the breaking down of the exceedingly complex structures and compounds making up the living plasma. Among the first outward signs of such disorganization is the loss of water. The cells of soft tissues lose their normal form, and in any case the tissue becomes more or less filled with gases. The protoplasts as such disappear, and in their place granular carbohydrate and proteid bodies are to be found.

Aside from the mineral substances composing the ash of such bodies, the organic compounds are made up for the most part of carbon, hydrogen, and oxygen. In the case of the proteids, there are added to these nitrogen, sulfur, and phosphorus. As to the exact nature of the compounds existing in the dead material, aside from the carbohydrates, very little is known. The same statement holds as to the nature of the decomposition which goes on without the intervention of saprophytic organisms. But it seems probable that oxidation does occur. This action, then, is the beginning of the more comprehensive process known as peat formation.

When plants or their organs die, under ordinary circumstances they are at once attacked by fungi and bacteria. The progress of dissolution is then greatly hastened, and the final disintegration is more complete. According to the operation of certain external factors, the destruction may involve two very different groups of organisms and result in bodies of very different chemical and physical properties. These two processes are known as eremacausis and putrefaction (**61, 39**).

Where access to oxygen is accompanied by favorable temperature and moisture conditions, the first of these processes, eremacausis, takes place. The formation of ordinary soil humus may be cited as an example. That oxygen plays the important rôle has been demonstrated both by experiment, and by the analysis of the gaseous and solid products. It has been shown, for example, that soils in which eremacausis is in progress contain CO_2 and O in inverse proportion to one another. Under constant volume, as the one increases the other decreases. It has been also shown by experiment that the process is wholly dependent upon the activities of certain lower plants. Among these members of the genera Mucor, Aspergillus, Penicillium, Saccharomyces, Micrococcus, Bacterium, Spirillum, Crenothrix, and Beggiatoa are most important.

The carbohydrates are by this means broken down to CO_2 and H_2O. The albuminoids and amides constitute the principal forms of the nitrogenous materials. Under the influence of these organisms, especially their katabolic processes, the oxygen unites with the carbon to form CO_2, the S is oxidized to H_2SO_4, the P to H_3PO_4, and the H to H_2O. The first form in which the nitrogen reappears is that

of ammonia. This is at once attacked by the nitrifying bacteria, and changed successively to the form of a nitrite and a nitrate. The two latter changes again involve the addition of oxygen.

If we consider only the temperatures occurring in nature, we may say that these activities increase regularly with the temperature. As to water conditions, it has been shown that in air-dry soil eremacausis is practically wanting, and that when the soil is filled with water it is reduced to a minimum. Between these two extremes lies an optimum at which there is sufficient moisture for the life of the organisms, and yet not enough to interfere with the diffusion of oxygen. An acid condition impedes, and a slight alkalinity favors, the production of both the carbon and the nitrogen compounds.

Eremacausis is then essentially a process of oxidation, brought about by lower organisms, whose activities are favored by a high temperature, a slightly alkaline medium, and free access to the air. Its products are simple compounds which may furnish food materials for the higher plants living on the substratum in which they are formed.

By putrefaction is meant that process of disintegration which occurs when organic matter decays in the absence of oxygen. Here again organisms are involved, but they belong for the most part to the anaerobes, and are wholly forms of bacteria. The process is essentially one of reduction.

Carbon dioxid is again the principal gaseous product, but its relative amount is greatly reduced. Along with it CH_4, H, H_2S, H_3P, N_2O, and N are produced in small quantities. In the manufacture of the carbon dioxid the oxygen is not only derived from the organic matter, but also from nitrous oxid, nitrites and nitrates which may be present. In the decomposition of cellulose, carbon dioxid and methane result from the hydrolysis of the cellulose molecule. Albumins at first break up into amido-acids, nitrogenous compounds of the aromatic series, and other little-known bodies. If the decomposition continues, the amido-acids in turn form ammonia and compounds of the fatty-acid series. The latter substances may still further disintegrate to carbon dioxid, hydrogen, and methane. Depending upon the stage in the progress of decomposition, we may find complex organic compounds, organic acids, and their salts, or comparatively simple substances.

As to the influence of external factors, high temperatures increase the rate of disintegration, while the presence of acids prevents its continuance, due to the killing of the bacteria involved. It is to be noted that the products of putrefaction, both intermediate and final, can be of little use in furnishing food materials for the higher plants.

With these two processes in mind, we may now consider the matter of peat formation as it occurs in this region. We have already seen how the substratum is being extended at the edge and renewed at the surface by the plants forming the outer zone of the bog vegetation. It consists of sedges, especially forms of Carex and Eriophorum. Each year these plants send up stems and leaves from the matted rhizomes. At the approach of winter these are killed, and the snow later on aids in bringing them down to the water level. In the spring the water covers almost the whole of this zone to the depth of several inches. With the gradual lowering of the water level and the coming of warmer temperatures, the conditions for eremacausis are made favorable. If the water is approximately neutral in its chemical reaction, the fungi and bacteria begin the work of disintegration, which if continued would result in the complete destruction of the vegetable débris. However, on account of the great demand for oxygen, the process can be carried on only near the surface of the water. Even at a depth of a few centimeters the rate of oxygen diffusion is so small, as compared with the demand for it, that practically all aerobic bacterial action is prevented. All of the surface waters which I have examined have been found to be teeming with bacteria.

Close upon the extension of the bog-sedge zone comes the sphagnum-heath zone. Here the surface is characterized by hollows and elevations, the latter frequently due to the upward growth of the sphagnum beneath the shade of the heath plants, but in some cases due to the building of mounds by ants. In the hollows the water stands above the substratum throughout a large part of the year and even during dry periods lies just at the surface. Unlike the sedges, the principal plants of this zone are evergreen. The sphagnum forms a continuous mat of living plants several centimeters in thickness, through which all of the oxygen must diffuse before it can be available for the eremacausis of the dead plant-material beneath. The cassandra, cranberry, and andromeda which compose the bulk of the shrubby vegetation add to the débris largely

by their leaves and underground stems. The former fall to the substratum as they die, but not at the close of each vegetative period. Consequently they are soon lost among the sphagnum, and there is no distinct annual layer added.

But beneath this layer of possible aerobic activity, the material would seem to be subject to putrefactive agencies. And there can be no doubt that such destructive processes are carried on in those situations in which the acidity of the soil solution does not preclude the existence of the anaerobic bacteria.

Among the taller shrubs and trees, such as *Vaccinium corymbosum*, *Aronia nigra*, and *Larix laricina*, the defoliation takes place each autumn. As these plants are of relatively large size, the bulk of the material forms a noteworthy annual addition to the substratum. When to this is added the twigs and small branches which fall each season, we can understand the fact that the substratum is almost entirely free of surface water. Usually the ground-water level lies 5–10 cm below. But the substratum has a high water-capacity and is kept constantly moist. Where the sphagnum covering is wanting for one reason or another, the dark color of the surface peat shows how much more complete is its disintegration as compared with that of the other zones. This condition is made possible by its position relative to the ground water. On the other hand, as will be shown later, the temperature conditions are more favorable in the zones of herbaceous and shrubby vegetation.

Most of the basins in which peat formation is going on actively, are subject to considerable variation in water level, both seasonal and annual. During the last two years the rainfall has been considerably above the normal in lower Michigan, and many of these bog areas were flooded. At West Lake, for example, a large part of the tamarack area was covered with water to a height of several inches above the level of the roots. Most of the basins are also subject to higher water level in the spring and during prolonged rainy periods. Accompanying such changes there are great differences in the rate and manner of decay. High water, in so far as it excludes oxygen, favors putrefaction; if it comes as a result of heavy rains, it decreases the acidity of the soil solution, increases its oxygen content, and at least for a short time favors the growth of the saprophytes causing eremacausis. Low water level exposes a much greater bulk of the

substratum to disintegration, and favors the carrying away of the products of decomposition; in general, it favors eremacausis. In the samples of water which I have examined at various times from the same depressions, there have been marked variations within short periods of time in the color of the water and in the presence of such animals as Daphnia and Cyclops. No attempt has been made to count or even separate the bacteria present, but it is probable that they too vary with the color of the water and the animal life.

When the bog land has been cleared and ditched, the marked increase in the rate of decay is apparent. Eremacausis becomes exceedingly active, and in the course of a few years the substratum is reduced to a brownish-black, pulp-like mass. If continued, this goes to form "muck," a substance which when dry is powdery and somewhat resembles soot. During these processes of decay there occurs a succession among the organisms present. The accumulation of disintegration products makes the medium unfavorable for the continued existence of the organism involved in their production. At the same time it may furnish optimum conditions for the development of other forms. An acid medium favors the growth of the Phycomycetes, while alkalinity favors the bacteria. In such regions as this, where the underground waters are alkaline, the latter fact, together with fluctuations in the ground-water level, may have an important bearing upon the presence of more thoroughly decayed peat and of a distinct depression about the margins of many of the bogs.

If to the factors of relative scarcity of oxygen and the acidity of the soil solution is added the occurrence of temperatures considerably lower than those of the surrounding uplands, it is not difficult to understand why a large part of each year's vegetative products should escape complete destruction. In our estimate of the bog substratum as a habitat for higher plants, the strong competition with the microscopic plants to which the former are subject in the acquisition of oxygen for their underground parts, must be emphasized.

THE PHYSICAL AND CHEMICAL PROPERTIES OF PEAT.

The peat formed through the agency of the bog sedges and their attendant plants has a fibrous and matted appearance. The structures of the various dead stems, roots, and leaves have suffered but slight

alteration. They were originally strongly cuticularized, and this has aided in their preservation. The color is commonly a pale yellowish-brown. During life these plant materials become strongly matted and interwoven, and this structure frequently persists. It is this structure that gives to the Carex-Eriophorum zone in many lakes its strength to support heavy bodies. A man's weight will carry the substratum a foot beneath the surface of the water, but it seldom breaks under the strain. In the case of lakes where this zone is unusually developed, it may cover a large part of the lake surface and be of great importance in the filling in of peat. In such cases the deposition takes place largely by the gradual falling of material from the under side of the floating substratum. On account of the slight weight of the material, it does not descend and produce a compact deposit on the bottom, but forms a sort of thick liquid peat.

The sphagnum-shrub zone, where well developed, usually shows a brown peat beneath it. It is composed largely of sphagnum and the semi-decayed twigs, rhizomes, and leaves of the other plants. It is distinctly fibrous, but of a type different from that of the sedge zone; the fibers are short, and the material is not nearly so tenacious.

Under the tamaracks a large part of the annual peat increment is made up of the tamarack needles, though mosses (Hypnum, Sphagnum, and Polytrichum) usually are of importance in this connection. The color is reddish-brown and darker than that of the shrubby zone. The fibrous structure is still less apparent, though present.

When these bogs have been burned over and partially drained, there frequently comes in a dense ground covering of moss (Polytrichum). In such cases the peat continues to accumulate, largely through the agency of this plant. In such situations the peat is a reddish-brown, and the plant structures have practically disappeared through decay. Below the upper layer, the peat when moist has the sticky, clayey properties of well-decomposed peat.

One other well-marked stage is shown in the areas of muck land now under cultivation to onions and celery. Under the influence of drainage and tillage, the disintegration is nearly complete. All plant structures have disappeared, the humous acids have been largely neutralized or washed out, and there is left only a fine, powdery, brownish-black "muck."

The following table shows some other physical properties of these several varieties of peat.

	Eriophorum Zone Peat	Fresh Sphagnum	Cassandra-Sphagnum Zone Peat	Tamarack Zone Peat	Chelsea Bog Peat	Onion Marsh Muck
H_2O-capacity % by volume.....	87.0	78.0*	91.0	84.0	82.0	75.0
H_2O-capacity % by weight.....	892.0	1550.0	960.0	530.0	477.0	283.0
Air dry H_2O-content %.....	8.5	10.6	10.0	10.0	10.0	10.0

*Low volume percentage due to air present in tissues.

These measurements were made by placing the peat samples in a zinc cylinder of 600 cc capacity. The bottom of the cylinder was closed with a wire gauze cap. The moist peat was tamped into the cylinders with as nearly uniform a stroke as possible. The cylinders were then set in a dish of water for eighteen hours, after which the cylinder was removed and allowed to drip. When all dripping had ceased, the cylinder was weighed. The peat was then removed and allowed to dry at room temperature, and again weighed. Finally it was dried at 110° C., and the absolute weight determined. As usual in such measurements, considerable irregularity was shown by the different samples, owing to the difficulty of removing the air, and of packing to the same degree. However, the figures bring out clearly the fact that sphagnum more than any other plant influences the water-capacity of a peat containing it. The eriophorum peat has a lower capacity, owing to its coarse fibrous structure. Of the series examined, the highest water-capacity was found in the cassandra zone. The effect of further decay and destruction of the plant tissue is shown by the reduction in water-capacity of the last three members of the series. The percentages are of interest in connection with the utilization of such lands for agricultural purposes, in showing the difficulty of proper drainage. It is the experience of the men who ditch these bogs that until the peat has reached the condition termed "muck" the ditches act only with extreme slowness.

Chemically, peat or humus is made up of varying quantities of several substances of a rather indefinite character, which are commonly classified among the dehydration products of the carbo-

hydrates. These bodies not only occur in nature, but may be artificially produced by the action of strong acids on starch, sugar, and cellulose. The relation of nitrogen to these bodies is still unknown. Principally on the basis of color and solubility in alkalies and acids, there are several substances distinguished. Ulmin and ulmic acid are brown, and are early products of decomposition. Humin and humic acid are black, and occur more abundantly where eremacausis has been active for a long time. Crenic and apocrenic acids appear to be further oxidation products; the former is colorless, and the latter varies from yellow to brown. MAYER believes these bodies to be organic nitrogen compounds (**36**), and on this basis STOCKBRIDGE (**50,** p. 135) explains the insolubility of peat soils and the presence of the unavailable nitrogen in peat. Beside these substances xylic, saccharic, and glucinic acids have been recognized. Although great advances have been made in soil chemics, it seems strange that the only suggestion of formulæ for these substances was made by MULDER in 1861 (**38**).

Humic acid forms water-soluble compounds with the alkalies, and to these are due largely the brown colors of the bog waters. The color may be produced by the presence of free humic acid. With the alkaline earths humic acid forms insoluble or difficultly soluble compounds. Hence there is slight chance of lime and magnesia penetrating from the surrounding soil into the peat deposits.

During the changes which the plant material undergoes in the process of peat-making there are alterations in the relative amounts of volatile hydrocarbons, fixed carbon, and ash—using these terms as in ordinary coal analyses.

	Eriophorum Stems and Leaves	Sphagnum	Eriophorum Zone Peat	Cassandra Zone Peat	Tamarack Zone Peat	Onion Marsh Muck
Volatile combustible	68.2	67.0	62.0	54.0	53.0	45.7
Fixed carbon.....	21.0	17.9	21.8	22.9	23.4	21.8
Ash.....	3.8	4.5	7.4	13.8	13.6	22.5
H_2O.....	7.0	10.6	8.8	9.3	10.0	10.0

The proportion of volatile combustible matter decreases regularly as the humification proceeds. The ash regularly increases, while the air-dry water content shows but slight modification.

(*To be continued.*)

BRIEFER ARTICLES.

NOTES ON NORTH AMERICAN WILLOWS. I.

(WITH PLATES XII AND XIII)

Salix Gooddingi, n. sp.—A shrub or small tree 2–3^{m} high: twigs straight, slender, yellowish, only slightly shining, glabrous or finely puberulent just above the axils of the short fertile branches (very young shoots probably pubescent): leaves on fertile twigs lanceolate or narrowly elliptic-lanceolate, sharply acute or sometimes abruptly short-acuminate at the apex, acute at the base, 2.5–4.5^{cm} long, 6–10^{mm} wide (probably considerably larger on sterile shoots), entire or sparsely to closely glandular-serrate, frequently somewhat falcate; usually glabrous, or puberulent to finely silky-pubescent when young, especially near the base, becoming entirely glabrous with age, dull green on both sides, scarcely paler beneath; midrib distinct, yellowish, nerves not prominent; petioles pubescent, 1–3^{mm} long; stipules none: aments appearing with the leaves, solitary, terminating short lateral leafy pubescent branches which are 1–2.5^{cm} long, and bear 3–6 leaves; pistillate abundantly produced, slender, rather lax in fruit, 3–5^{cm} long, the rachis densely gray-pubescent: capsules short ovate-conic, 3–4^{mm} long, densely gray-tomentose, long pedicelled; pedicels densely gray-tomentose, 1.5–3^{mm} long; scales yellow, linear-oblanceolate, obtuse, 0.5^{mm} wide, 2.5–3^{mm} long, white-tomentose on both sides; style none; stigmas divided, short, thick, reddish-brown.—*Plate XII, figs. 1, 2.*

S. Gooddingi belongs to the section LONGIFOLIEAE and is probably most nearly related to *S. Bolanderiana* Rowlee, from the Yosemite Valley, California. It is easily separated from all other species by the long pedicels, nearly equalling the capsule in length. The foliage bears a superficial resemblance to that of *S. nigra* Marsh.

The type was collected by LESLIE N. GOODDING, of the University of Wyoming, no. 689, Flora of Nevada; ditch banks, Muddy Creek, May 2, 1902. Muddy Creek is a tributary of the Virgin River, which flows into the Colorado in Lincoln County, in extreme southeastern Nevada. The specimen consists of pistillate shoots bearing numerous nearly mature aments. No other material has been seen. The species is named in honor of the collector, who has furnished the following notes on the plant and the locality in which it was found:

"Collected along a ditch where it grew quite profusely, 8–10 feet high. It grows in patches or clumps, much the same as *S. exigua* and *S. fluviatilis*, only with a tendency to branch more from central axes. It was quite abundant where collected, appearing along the ditch for some distance, but I believe its distribution quite local,

as it was collected at no other place. It doubtless is common along the Muddy. The region of the Muddy is a very barren desert, scarcely anything growing except along the streams or ditches. The water and the soil are quite salty and there are low hills of salt which border along the Muddy and the Virgin. The willow, however, seeks the stream banks and ditches, the little marshy places being too alkaline."

Salix Tweedyi (Bebb) n. comb. *S. Barrattiana Tweedyi* Bebb, Contrib. U. S. Nat. Herb. **3**:572. 1896.—A shrub, with short stout divaricate branches; bark on the older twigs gray, somewhat shining, on younger twigs chestnut to deep reddish-brown, usually quite glabrous except the twigs of the season,which are commonly densely pubescent with spreading gray hairs: buds large, 6–10^{mm} long, chestnut, thinly pubescent with long hairs, at length glabrate: leaves elliptical and acute at both ends, to oval, acute to somewhat obtuse at the apex, acute to rounded at the base, or subcordate in mature foliage, occasionally obovate-oval, rounded at the apex, especially when young, 5–7^{cm} long, 2.5–4^{cm} wide; glabrous on both sides or the young leaves sparsely pubescent above with long gray hairs, green above, paler but not glaucous beneath; margin finely and closely glandular-denticulate or serrate, the yellowish glands projecting at right angles to the apparently entire margins of the young leaves, in mature leaves the glands on the points of irregular, spinulose teeth, perpendicular or sometimes pointing toward the apex of the leaf; petioles 8–15^{mm} long, frequently tomentose; stipules large, broadly reniform, somewhat clasping, 5–14^{mm} long, glandular spinulose-denticulate: pistillate aments precocious, sessile, stout, lateral and terminal, spreading, often curved, 4–6^{cm} long, 1.5–1.8^{cm} wide in fruit: capsules green and glabrous, or sometimes finely pubescent near the apex, ovate-conical, pedicellate, 7–8^{mm} long when mature; pedicel 1^{mm} long, smooth; style 1.5–2.5^{mm} long, green, stigmas divided, about 0.5^{mm} long; scale obovate, acute or obtusish, 2–2.5^{mm} long, black, clothed with long, straight, white hairs; gland about 1^{mm} long.—*Plate XII, figs. 3–7.*

WYOMING: head of Big Goose Creek, Big Horn Mountains, nos. 11 (the type) and 12, *Frank Tweedy*, July 15–24, 1893; "along streams in Teton Basin, July. With ovaries nearly smooth! Professor *Porter*." J. M. Coulter, 1872.

This last specimen is listed by COULTER[1] under the name of *S. Barrattiana*. In the U. S. National Herbarium the Hayden Survey specimen is ticketed "Trail R. Mts., Idaho Terr." Trail Creek, along which the party worked, is, however, in southwestern Montana, not far north of the Yellowstone Park. The sheet carries pistillate aments and both young and mature foliage. Though collected twenty-one years earlier than the type collection, it is not mentioned by BEBB, and was probably unknown to him.

The variety was named and described by BEBB in an article by J. N. ROSE,

[1] Hayden, Ann. Rept. U. S. Geol. Surv. Terr. **6**:781.

based on a small collection of plants made by FRANK TWEEDY, of the U. S. Geological Survey. His collections were made in the Big Horn Mountains, "between longitude 107° and 107° 30′ and latitude 44° 30′ and 44° 40′, chiefly on the headwaters of the east and west forks of Big Goose Creek and on the high divide between these streams and Shell Creek."

The original description and the accompanying data are as follows:

"Leaves at first thinly overspread on the upper surface with floccose hairs, soon smooth and green both sides; capsules glabrous. In bogs and along mountain streams, altitude 2,460 to 3,080m (8,000 to 10,000ft). Head of Big Goose Creek, Big Horn Mountains, July 15 (nos. 11 and 12)."

BEBB, after noting the original and few subsequent collections of the rare *Salix Barrattiana* and remarking on its silky leaves and capsules, continues:

"That there should be more or less variation in this vesture was to be expected from what is known of the two most nearly allied species. *S. Hookeriana* was first described as having 'very smooth' capsules, but subsequent observations have shown that they are more frequently tomentose, and a like variation, though in less degree, prevails in the case of *S. Richardsoni;* but in neither is this variation so pronounced as to lessen the surprise with which we find the one species of the group heretofore most conspicuous for its silky vesture, appearing, as in Mr. TWEEDY'S specimens, so markedly glabrate. The leaves, and in fact the aments as well, bear a very close and deceptive resemblance to some forms of *S. Barclayi;* but the aments are closely sessile, terminal as well as lateral, the styles longer and the stigmas bifid; the leaves alone could scarcely be distinguished one from the other."

A study of the type material and of later collections leaves no doubt that this willow is specifically distinct from *S. Barrattiana*. Not only do the nearly glabrous leaves and the glabrous capsules serve to distinguish it, but the leaf margin thickly set with conspicuous glands is a marked character.

The varietal name proposed by BEBB was "*denudata*," but as this was preoccupied by *S. commutata denudata* Bebb (1888) ROSE substituted the name "*Tweedyi*" and credited it to BEBB, whose name appears in the text as the author. COCKERELL has since contended[2] that ROSE and not BEBB must be considered the author of the variety. This view, however, cannot be accepted.

Salix Wolfii Idahoensis, n. var.—Leaves usually densely silky-villous with shining hairs, giving a decided luster to the surface, scarcely blackening in drying: capsules 3–4mm long, thinly but permanently silky pubescent; style about 1mm long.

WYOMING: Mammoth Hot Springs, Yellowstone National Park, no. 5655, *Aven* and *Elias Nelson*, July 3, 1899; Swan Lake Valley, Yellowstone National Park, alt. 7300ft (2225m), *F. H. Knowlton*, July 9, 1888.

MONTANA: Madison Cañon, *J. M. Coulter*, Hayden Survey, 1872. The specimen so labelled in the U. S. National Herbarium (accession no. 253,723) bears on the label, "Madison Cañon, Idaho Ter.," which must certainly be an error, since the

[2] BOT. GAZETTE **22**: 268. 1896.

Madison Cañon explored by the Hayden Survey in 1872 is in Montana, not far from the boundary of the Yellowstone Park. This specimen was probably listed under the name of *Salix glauca* L., which is credited by COULTER in his list[3] to the "Upper cañon of the Madison." *S. Wolfii* is, of course, not mentioned, because it was not published until six years later, in 1878.

IDAHO: Forks of Wood River, alt. 6000^{ft} (1800^{m}), no. 3399 (type), *L. F. Henderson*, July 25, 1895.

OREGON: Banks of Wallowa River, mouth of Hurricane Creek, no. 2400, *W. C. Cusick*, June 11, 1900.

The relationships of this little willow are all with *S. Wolfii* Bebb, from the typical form of which it differs mainly in the silky-pubescent capsule and the rather more silky leaves. The different specimens show considerable variation in the amount of pubescence on the capsules. In general, the specimens from the more northwestern localities show the denser pubescence, both on leaves and capsules. In some cases they tend toward a glabrate condition in age. In *S. Wolfii* the capsules are glabrous even when young. This variety is found from the Yellowstone Park northwestward across Montana and Idaho to eastern Oregon. The species is found from central Colorado to Montana and Idaho.

Salix Nelsoni, n. sp.—A shrub, 1.2–3^{m} high, freely branching, very leafy; twigs shining, the older gray with a reddish tinge, the younger bright chestnut or darker, and often drying dark: buds large, smooth, chestnut, 7–9^{mm} long, beaked: leaves petioled, petioles 3–7^{mm} long, smooth; stipules none; blades oblanceolate or rarely narrowly lanceolate, acute at both ends, cuneate at the base, 8–15^{mm} wide, 3–5.5^{cm} long, entire (except as noted below), the margin somewhat involute, especially toward the base; glabrous, or thinly silky villous when young, green and very shining above, pale and somewhat glaucous below; primary veins prominent, usually elevated and rather greenish-yellow on the upper surface, prominently reticulate below by the elevation of both primaries and secondaries;[4] apical and subapical leaves on sterile shoots narrowly elliptical, the margin shallowly glandular crenate-serrate: pistillate aments sessile with sometimes a few small foliaceous bracts at the base, spreading, slender and cylindrical when young, very much thickened in fruit, 1.5–3^{cm} long: capsules silky pubescent, sessile, 5–6^{mm} long; styles entire or rarely bifid, 0.3–0.5^{mm} long; stigmas smooth, 0.7–1.0^{mm} long, dark; scales dark, ovate, acute, clothed on both sides with long white hairs: staminate aments not seen.—*Plate XIII, figs. 8–11.*

COLORADO: Little Fountain Creek (south of Pike's Peak), alt. 9200^{ft}, no. 12, *J. C. Blumer*, September 5, 1903; Mt. Lincoln, Park Co., alt. 12,000^{ft}, *J. M. Coulter*,

[3] Ann. Rept. U. S. Geol. Surv. Terr. **6**:782. 1873.

[4] In the type the primaries and sometimes also the secondaries on the upper surface are very broad and deep green in color, giving a strikingly beautiful effect, which is not so evident in other specimens.

July 9, 1873; Beaver Creek, Larimer Co., roadsides in pine woods, no. 1440, *L. N. Goodding*, July 4, 1903.

WYOMING: Centennial Valley, no. 1754, *Aven Nelson*, August 18, 1895; Centennial, Albany Co., bogs, no. 8822, *Aven Nelson*, August 7, 1902; Laramie Peak, Albany Co., along the creek, in clumps, 4–10 ft high, no. 7580 (type), *Aven Nelson*, July 13, 1900; head of Big Goose Creek, Big Horn Mountains, no. 47, *Frank Tweedy*, July 15–24, 1893.

ALBERTA: Banff, low ground, side of road to Devil's Head Lake, alt. 4500 ft, no. 2253, *W. C. McCalla*, June 8 and August, 1899.

This beautiful willow is found at high altitudes in the mountains of Colorado and northward. It is most closely related to *S. chlorophylla* Anderss. and the pistillate aments closely resemble those of that species. It is readily distinguished by the oblanceolate leaves which, when mature, are prominently nerved above and reticulated beneath. Authentic staminate material has not been seen.

I take pleasure in dedicating this species to Professor AVEN NELSON, of the Rocky Mountain Herbarium, who has made available so much valuable material in this difficult genus.—CARLETON R. BALL, *U. S. Department of Agriculture, Washington, D. C.*

EXPLANATION OF PLATES XII AND XIII.

PLATE XII.

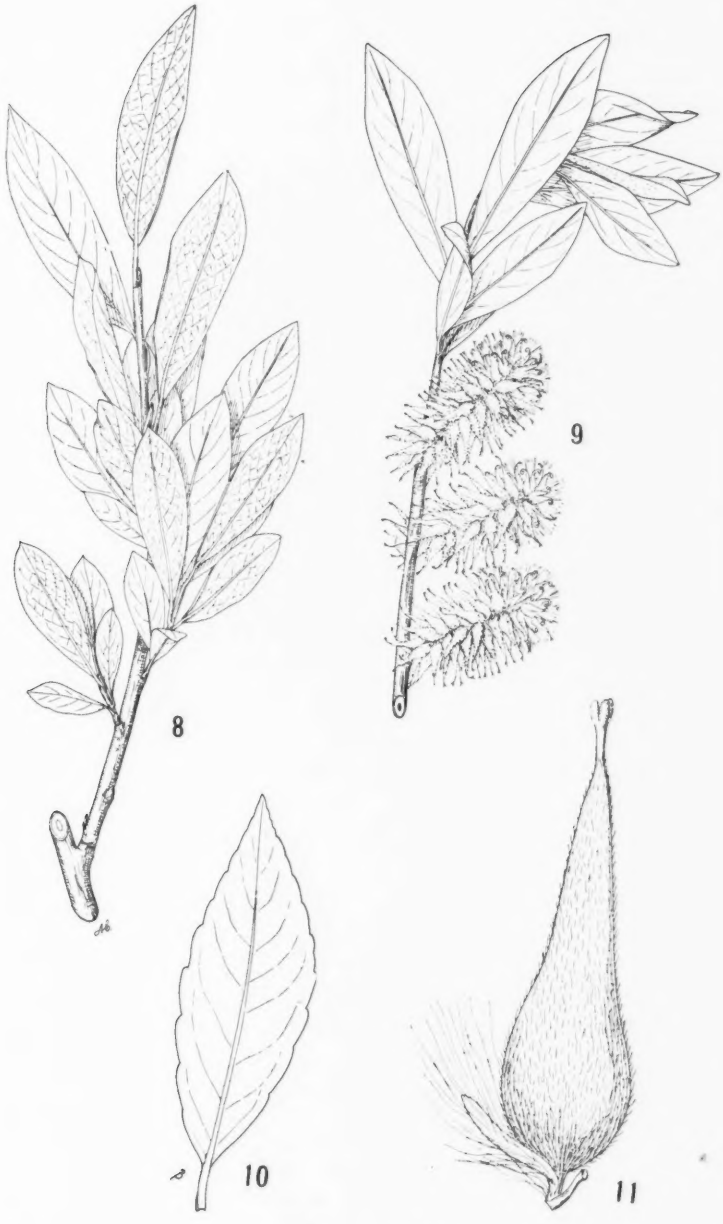
FIGS. 1 and 2. *S. Gooddingi* Ball; *fig. 1*, fruiting branch, natural size; *fig. 2*, capsule and scale. ×10.

FIGS. 3–7. *S. Tweedyi* (Bebb) Ball. *Fig. 3*, sterile twig; *fig. 4*, pistillate ament; *fig. 5*, mature leaf showing stipule and bud; *fig. 6*, capsule (×10); *fig. 7*, outline of margin of young leaf showing glands. ×10.

PLATE XIII.

FIGS. 8–11. *S. Nelsoni* Ball; *Fig. 8*, Sterile twig, from type; *fig. 9*, fruiting branch; *fig. 10*, elliptical apical leaf; *fig. 11*, capsule, ×10.

BALL on SALIX



BALL on SALIX

CURRENT LITERATURE.

BOOK REVIEWS.

Research methods in ecology.

We seldom receive a work whose central idea is essentially new, but Dr. Clements's latest volume[1] almost if not quite attains this distinction. The ecology of our day is to be divided into the true and the false, and most of it, unfortunately, is of the latter type. It is a subject which, on the surface, seems to lend itself well to the lovers of fads, and there are many "contributions" to ecology which consist of a hasty gathering together of notes made in leisure moments during summer holidays. The true ecology, the ecology that is to be, is developed only by the most arduous and long-continued work. The dilettante ecology is to pass away, and one of the foremost causes for this change will be this new book of Clements.

The opening chapter reveals the author's ideals as to the meaning and place of ecology, its historical development, its present status (largely deplorable, because so many tyros are making desperate attempts to enter the new and inviting field), and its relationships with other botanical lines of research. The second chapter, entitled the habitat, considers in detail the various ecological factors, and will be of extraordinary value to ecological research, because it recounts in full the ingenious and multiform methods that have been employed by the author in the study of the Nebraska and Colorado vegetation. Soil, water-content, atmospheric humidity, and light are regarded as direct factors, and hence more attention is paid to them than to indirect factors (such as temperature), or remote factors (such as altitude). The various instruments of precision, such as psychrometers, psychrographs, photometers, thermographs, and many others, are figured and their use explained in full. For the physical and physiological water-content of the soil, the author proposes respectively the terms holard and chresard. The word ecograph is employed as a general term embracing all instruments that are used for the determination of physical habitat factors. Much space is devoted, and properly, to the intelligent expression of results; we greatly regret that the metric system is not exclusively employed in these tables.

"The plant" is the title of the third chapter, and an admirable survey is given of the more important adjustments and adaptations; the former word is used to denote functional response, the latter structural response. These most important distinctions are often disregarded, thus leading to deplorable confusion. Response to water is termed hydroharmose, to light photoharmose. In this, as

[1] Clements, F. E., Research methods in ecology. pp. xvii+334. Lincoln, Neb.: The University Publishing Co. 1905.

in the preceding chapter, methods of measurement are described, but of course they are much less satisfactory. This is a difficulty that in part inheres in the more complex phenomena that are to be measured, but also in part in the fact that physiologists have failed to cultivate as they might this fertile and enticing field. One might wish for a softening of the teleological terminology, as in p. 129 and p. 143; whether there is or is not an ultimate teleology, it seems wiser to discard its vocabulary. It seems to the reviewer that expressions implying purpose are in part responsible for the disfavor in which ecology is sometimes held. The close of this chapter is devoted to a consideration of experimental evolution, and a full account is given of natural, habitat, and control cultures.

The final chapter considers plant formations, and their study is based on the quadrat method, much of which the author has previously published. Among the subjects here treated are cartography, photography, and formation herbaria. The discussion of the development and structure of vegetation is much like a separate treatise on the same subject already reviewed in these pages. Methods for the study of succession and competition are given. At the close is a helpful glossary.

One can scarcely praise this work too much; it is what is needed to prevent ecology from falling into a swift and merited disfavor. If read and pondered, it will prevent the thoughtless from entering the ecological field, and it will serve the higher end of directing the thoughtful as to the methods of procedure.—H. C. COWLES.

MINOR NOTICES.

THE ADMIRABLE illustrations of vegetation issued by KARSTEN and SCHENCK have frequently been noted in the GAZETTE. A somewhat similar idea has been pursued by WETTSTEIN,[2] who has issued reproductions of a large number of the Brazilian photographs secured by F. VON KERNER and himself on their recent journey to South America. There are fifty-eight plates in phototype, four colored plates, and six text figures. In nearly every instance the original photographic work and the subsequent reproductions have been admirable, and one who has never visited the Brazilian tropics may yet gain herefrom an accurate idea of their general appearance. Not only are there illustrations from the tropical and subtropical rainy forests, but the savannas and the mountains are figured as well.—H. C. COWLES.

SCOTT[3] has given an exceedingly interesting and comprehensive account of the recent development of knowledge in reference to the seed plants of the Carboniferous. It will prove very useful to those who have neither the time nor

[2] WETTSTEIN, R. VON, Vegetationsbilder aus Südbrasilien. Leipzig and Vienna. 1904.

[3] SCOTT, D. H., The early history of seed-bearing plants, as recorded in the Carboniferous flora. The Wilde Lecture. Manchester Memoirs **49**: no. 12. pp. 32. *pls.* 3. 1905.

the opportunity to read the more extensive and scattered papers that deal with the subject.—J. M. C.

THE SECOND and concluding part of the second supplement (1896–1900) of the *Kew Index* has appeared.[4] A notice of the first part appeared in BOT. GAZETTE **39**:68. 1905. The second part includes the letters L–Z, and also six pages of corrections and additions.—J. M. C.

NOTES FOR STUDENTS.

THE PROBLEM OF HEREDITY.—THIS important contribution[5] is similar in plan to the famous *Cytologische Studien aus dem Bonner Institut* which played such an important part during the centrosome controversies. The present work deals with the problem of chromatin reduction and with theoretical considerations connected with this problem. STRASBURGER[6] writes on typic and allotypic[7] nuclear division, ALLEN on the behavior of the nuclear substance during synapsis in the pollen mother-cells of *Lilium canadense*, MIYAKE on the reduction division in the pollen mother-cells of certain monocotyledons, and OVERTON on the reduction division in the pollen mother-cells of certain dicotyledons.

The four writers agree that the nuclear network consists of both linin and chromatin, and all but ALLEN describe a reducing or qualitative division of the chromatin during the first mitosis in the pollen mother-cell.

STRASBURGER studied various pollen mother-cells and also the megaspore mother-cells, all of which are drawn from nuclei of the ovary walls and placenta of *Galtonia candicans* and *Funkia Sieboldiana*. His figures represent close series from the resting stage to telophase. Considerable variation in the number of chromosomes was found in both forms. The bearing of this fact upon the theory of the individuality of the chromosomes is discussed, and the conclusion is reached that the number of chromosomes is fixed by heredity, but not within such rigid limits as to exclude some variation in vegetative cells. The definite

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[4] Index Kewensis plantarum Phanerogamarum: supplementum secundum nomina et synonyma omnium generum et specierum ab initio anni MDCCCXCVI usque ad finem anni MDCCCC complectens. Ductu et consilio W. T. Thiselton-Dyer confecerunt herbarii horti regii botanici Kewensis curatores. Leucocoryne–Zygostates et emendanda addenda. Pp. 105–204. Oxford: Clarendon Press. 1905. 12*s*.

[5] STRASBURGER, E., ALLEN, C. E., MIYAKE, K., and OVERTON, J. B., Histologische Beiträge zur Vererbungsfrage. Jahrb. Wiss. Bot. **42**:1–153. *pls. 1–7*. 1905.

[6] STRASBURGER, E., Typische und allotypische Kernteilung. Jahrb. Wiss. Bot. **42**:1–70. *pl. 1*. 1905.

[7] By typic divisions are understood the ordinary vegetative or somatic divisions; the allotypic divisions are the two divisions usually called the heterotypic and homotypic divisions. The term allotypic is equivalent to the term maiotic as used by FARMER. STRASBURGER would restrict the term atypic to pathological mitosis.

number seems essential only in the gonotokonts,[8] when it insures the pairing of paternal and maternal chromosomes. The chromosomes of a nucleus probably differ among themselves, and it is almost certain that the two chromosomes of each pair pass to different nuclei. The heterotypic and homotypic mitoses differ in that the first distributes to the daughter nuclei the paired, univalent, and already longitudinally split paternal or maternal chromosomes, while the second separates the longitudinal halves of chromosomes whose longitudinal splitting was already prepared during the prophase of the first mitoses. The behavior of chromatin in fertilization and in parthenogenesis is discussed in detail. STRASBURGER'S paper closes with a reinvestigation of the peculiar hybrid, *Cystisus Adami*, showing that there is no cytological basis for the assumption that it is a graft hybrid.

ALLEN[9] describes, in greater detail than in his previous papers, the behavior of the nuclear material from the resting reticulum up to the spirem of the heterotypic division. Some of the principal features of this period are: (1) a collecting of the materials belonging to the somatic chromosome, (2) an approximation and pairing of two somatic (presumably paternal and maternal) groups of substances, (3) a stretching of the visible nuclear structures (except the nucleolus) into slender threads which come to lie side by side and finally fuse, (4) the disappearance of anastomoses and the formation of a continuous spirem, and (5) a uniseriate distribution of chromosomes in each thread, the opposition of the chromosomes of parallel threads, followed by the fusion of the threads and union of the chromosomes in pairs.

MIYAKE[10] studied the reduction division in the pollen mother-cells of Galtonia, Iris, Lilium, Allium, Funkia, and Tradescantia. In synapsis there is not a pairing of fully formed chromosomes, but of groups of chromatic substance. These groups are drawn out into a double thread, which may be regarded as approximated chains of chromosome pairs. The chromosomes, paired at this early stage, continue to grow as pairs until mature. In the heterotypic mitosis the two members of each pair are separated and pass to opposite poles. Consequently, this mitosis is a reduction or qualitative division. The second mitosis is a doubling (*Äquationsteilung*) division.

OVERTON[11] studied the reduction division most thoroughly in *Thalictrum purpurascens*, but for comparison used also *Helleborus foetidus*, *Podophyllum*

[8] The term, *Gonotokonten*, proposed by LOTSY, applies to spore mother-cells of plants and to the primary spermatocytes and primary oocytes of animals.

[9] ALLEN, C. E., Das Verhalten der Kernsubstanzen während der Synapsis in den Pollenmutterzellen von *Lilium canadense*. Jahrb. Wiss. Bot. **42**:71–82. *pl. 2*. 1905.

[10] MIYAKE, K., Ueber Reduktionsteilung in den Pollenmutterzellen einiger Monokotylen. Jahrb. Wiss. Bot. **42**:83–120. *pls. 3–5*. 1905.

[11] OVERTON, J. B., Ueber Reduktionsteilung in den Pollenmutterzellen einiger Dikotylen. Jahrb. Wiss. Bot. **42**:121–153. *pls. 6–7*. 1905.

peltatum, *Calycanthus floridus* and *Campanula grandis*. In very young pollen mother-cells he finds masses of chromatin which he calls prochromosomes. The prochromosomes are in pairs and their number is the same as that found in somatic nuclei. The parental chromosomes maintain their identity during synapsis. The first division is a reduction division in which entire univalent chromosomes, which were united during synapsis, become separated. The second mitosis is a doubling division. It is probable that the two halves of the presynaptic chromosomes are of paternal and maternal origin, and that during synapsis there is a union of paternal and maternal elements.—C. J. CHAMBERLAIN.

THE INHERITANCE of coat characters in guinea-pigs and rabbits has been studied by CASTLE[12] during the last five years, and his first detailed report has appeared in the series of papers of the Station for Experimental Evolution. In breeding about 3,000 guinea-pigs and several hundred rabbits he finds that the following characters obey MENDEL'S laws, the first mentioned member of each pair of characters being dominant: pigmented coat *vs.* albino, rough coat *vs.* smooth, long coat *vs.* short. Albinism and long hair are conceived to be new characters and their recessiveness agrees, therefore, with the view that phylogenetically older characters dominate the newer; but the rough coat, which is dominant over smooth, is nowhere found among guinea-pigs in their native state and is likewise a new character. This shows, as has been done recently by CORRENS[13] also, that ancestral characters do not necessarily dominate the new characters in inheritance. The dominance of the rosetted or rough coat over the smooth may be considered as supporting CORRENS'S view that the morphologically higher dominates the lower, but this view is negatived in the dominance of short coat over long. It seems to be impossible at the present time to predict which of an uninvestigated pair of characters will be dominant.

The author draws a sharp distinction between recessive and latent characters, the latter being defined as "characters normally dominant, which have disappeared in recessive gametes beyond hope of recall, except under conditions of cross breeding which are in most cases not entirely clear." He expresses a doubt whether a recessive character may ever be latent, though there appear to be no *a priori* grounds for such a difference of behavior in the two kinds of characters.

In a case between certain white individuals and red, about half the offspring were black pigmented. The assumption that in these individuals two kinds of gametes were produced in nearly equal proportions, the one kind containing latent black, the other being entirely free from black, was proved by breeding tests of the non-black offspring, no black pigmented young resulting from these matings. This difference of behavior between the purebred race and the extracted recessives resembles BATESON'S experiences with sweet peas and stocks.[14]

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[12] CASTLE, W. E., Heredity of coat characters in guinea-pigs and rabbits. pp. 78. Washington: Carnegie Institution of Washington. 1905.

[13] See résumé in BOTANICAL GAZETTE **40**:235. 1905.

[14] See résumé in BOTANICAL GAZETTE **40**:313. 1905.

Several irregularities were noted, such as occasional imperfect dominance in combinations where one of the characters is usually fully dominant, but in these cases the blended condition in the first generation was followed by typical splitting in the second. Length of ears and lop ears of rabbits were found to blend in inheritance, the second and subsequent generations retaining the blended or intermediate condition.

The paper is illustrated with six plates of excellent halftone engravings, representing the various coat characters and their hybrid combinations. Ten of these engravings with a few others are reproduced in another paper[15] by the same author, in which his more important results are used to illustrate the recent advances in our knowledge of the laws of heredity and their practical applications in plant and animal breeding. This paper was read before the American Breeders' Association at its second meeting, at Champaign, Ill., February 1–3, 1905, and is also published without the plates in the Proceedings[16] of that organization.—G. H. SHULL.

THE SYMPOSIUM of six addresses on the mutation theory, delivered before the American Society of Naturalists at Philadelphia, December 28, 1904, has been published in full in *Science*. One of these addresses, which was published elsewhere, has already been noted in these columns.[17] CASTLE[18] discusses the subject from the standpoint of the animal breeding, illustrating with his results in guinea-pigs. He observed extra toes and long hair to arise as mutations and shows that long-haired and normal short-haired animals could coexist and interbreed freely without ever swamping the long-haired condition, as it behaves as a Mendelian recessive. Natural selection could then determine which if either of these forms should be eliminated. If inheritance is not sharply alternative the mutation would simply act to increase the fluctuating variability and could never become a racial character through natural selection.

In considering the relation of cytology to the mutation theory, CONKLIN[19] emphasizes the fact that all evolution must be the evolution of the germ-cells and is founded primarily upon cytological phenomena. The great morphological complexity of the germ-cells which recent studies have demonstrated, and the speaker's observations on the diffusion of chromatin from the nucleus to definite areas of the cytoplasm of the ascidian egg, are cited as favoring the hypothesis

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[15] CASTLE, W. E., Recent discoveries in heredity and their bearing on animal breeding. Pop. Sci. Monthly **66**:193–208. 1905.

[16] Proc. Amer. Breeders' Assn. **1**:120–126. 1905.

[17] MACDOUGAL, D. T., Discontinuous variation and the origin of species. Torreya **5**:1–6. 1905; and Science N. S. **21**:540–543. 1905.

[18] CASTLE, W. E., The mutation theory of organic evolution from the standpoint of animal breeding. Science N. S. **21**:521–525. 1905.

[19] CONKLIN, E. G., The mutation theory from the standpoint of cytology. Science N. S. **21**:525–529. 1905.

of "intracellular pangenesis." Modifications of the germinal organization are probably the immediate causes of evolution. Even a slight alteration in the unsegmented egg may result in a profound change in the adult as illustrated in the production of dextral and sinistral forms of mollusks by maturation taking place, now at the one pole, now at the other.

DWIGHT[20] concludes that evidences from human anatomy offer no support for the theory of evolution by minute changes, and that although they do not give any direct support to the mutation theory they are not in disaccord with it.

BAILEY[21] discusses the relation between taxonomy and evolution, pointing out some of the weak points in the present system of classification, particularly in that taxonomic systems are rigid and arbitrary, whereas the organic world is plastic and changing. He holds that the ideal taxonomy of the future must make no distinction between "natural" and "artificial" forms, and that the type of a species should be the real phylogenetic or biological type instead of the first specimen which chanced to be named. There can never be such a thing as a satisfactory "stable" nomenclature.

WHEELER[22] considers the mutation theory even more important in the explanation of the origin of new instincts, new functions and new habits of life, than for the origin of new morphological characters, especial mention being made of parasitic species and species with profound and sudden metamorphoses.—G. H. SHULL.

THE GERMINATION of *Coleochaete scutata* has been studied by ALLEN[23] who has paid particular attention to cytological features of the first and second divisions of the fertilized egg. Fertilization takes place in the summer. After resting during the winter, the fertilized egg segments into a number of cells, in each of which a zoospore is developed.

In the prophase of the first mitosis a condition is found which the author regards as a genuine synapsis, during which a fusion of somatic chromosomes occurs, as in his account of Lilium. The chromosomes formed from the spirem are bivalent, the line of separation corresponding to the earlier longitudinal splitting of the spirem. Occasionally the arrangement of chromatin granules suggests that the chromosomes may be quadrivalent. The number of chromosomes is probably thirty-two. No centrosomes or centrospheres could be distinguished. At the second division the chromosomes are longer and more slender than those of the first division. A cell plate is formed at each division. The two divisions correspond quite closely with the heterotypic and homotypic divisions

[20] DWIGHT, THOMAS, Mutations. Science N. S. **21**:529–532. 1905.

[21] BAILEY, L. H., Systematic work and evolution. Science N. S. **21**:532–535. 1905.

[22] WHEELER, W. M., Ethology and the mutation theory. Science N. S. **21**: 535–540. 1905.

[23] ALLEN, C. E., Die Keimung der Zygote bei Coleochaete. Ber. Deutsch. Bot. Gesells. **23**:285–292. *pl. 13*. 1905.

in pollen mother-cells of angiosperms. It seems probable that a reduction of chromosomes is effected during these two divisions. If this is correct, there is in Coleochaete no generation with the double number of chromosomes, except the zygote itself. There is no generation which could be called a sporophyte. Each cell of the spore mass which has usually been regarded as the sporophyte has the reduced number of chromosomes like the vegetative cells of the thallus.

The statement that there is no generation which could be called a sporophyte, seems to the reviewer to be a serious mistake. Riccia has a sporophyte just as truly as has Sequoia, the extent of its development being unessential as far as the logical presence of a sporophyte is concerned. The sporophyte generation in lower plants as well as in higher begins with the fertilized egg. Whether the egg then divides once, twice, or a million times, or not at all, neither strengthens nor weakens its title to the term, sporophyte. It seems to us that there is an important difference between extreme reduction and complete elimination.—C. J. CHAMBERLAIN.

ITEMS OF TAXONOMIC INTEREST are as follows: R. VIGUIER (Bull. Soc. Bot. France IV. **5**:285–314. 1905), in presenting the Polyscias group of Araliaceae, has described two new genera—*Tieghemopanax*, with 26 species; and *Bonnierella* with one species.—J. M. GREENMAN (Proc. Amer. Acad. **41**:235–270. 1905) has published descriptions of new species of angiosperms from the southwestern United States, Mexico, and Central America, the new genera being *Mimophytum* (Boraginaceae) and *Lozanella* (Urticaceae), both from Mexico, and the new species from the southwestern United States belonging to Cassia, Cedronella, Salvia, and Erigeron.—B. L. ROBINSON (*idem* 271–278), among diagnoses and notes relating to American Eupatorieae, has described new species in Ageratella (which here receives its first formal and detailed characterization as a genus), Fleischmannia, Piptothrix, and Eupatorium (5).—W. A. MURRILL (Bull. Torr. Bot. Club **32**:353–371. 1905), in a synopsis of the brown pileate species of North American Polyporaceae, describes the following new genera: *Coriolopsis* (2), *Flaviporus* (2), *Cerrenella* (2), *Nigroporus*, *Fomitella*, *Amauroderma* (3), and *Porodaedalea*.—C. L. GRUBER (*idem* 389–392) has described 3 new species of Crataegus from Berks Co., Pa.—PH. VAN TIEGHEM (Ann. Sci. Nat. Bot. IX. **1**:247–320. 1905) has established a new family *Irvingiaceae* upon the genus Irvingia and three allied genera, which have been associated heretofore with the Simarubaceae.—W. J. TUTCHER (Jour. Linn. Soc. London **37**:58–70. 1905), among other new Chinese plants, has described a new genus (*Dunnia*) of Rubiaceae.—OTTO STAPF (*idem* 79–115), in his "Contributions to the flora of Liberia," has described the following new genera: *Atroxima* (Polygalaceae), *Urobotrya* (Olacaceae), *Androsiphonia* (Passifloraceae), and *Afrodaphna* (Lauraceae). M. L. FERNALD (Rhodora **7**:146–150. 1905), in presenting the genus Arnica in northeast America, recognizes seven species, describing three as new.—J. M. C.

IN A PAPER read before the Royal Dublin Society, DIXON[24] answers recent

[24] DIXON, H. H., The cohesion theory of the ascent of sap. Notes Bot. Soc. Trinity Coll. Dublin **1**:203–216. 1905.

criticisms made on the cohesion theory of the ascent of sap by STEINBRINCK and by COPELAND.

STEINBRINCK established the fact that the walls of the conducting tracts are permeable to air and regards this as incompatible with the cohesion theory, since air diffusing through the tracheal walls would tend to break the continuity of the water columns within them, by the formation of free bubbles. In reply to this, DIXON states that the air in solution does not cause the rupture of a water column under tension; that the permeability of the walls does not necessitate the formation of free bubbles in the conducting tracts; and that even if bubbles are formed the current is merely deflected from that portion of the channel.

In regard to the results obtained by COPELAND, that the ascent of water in his "tree" was due not to a pull transmitted downward by the cohesion of water, but to some force which is measured by the difference in pressure as indicated by the manometers at the bottom and 8.4^{m} from the bottom of the "tree," DIXON shows that according to COPELAND a column of water 8.4^{m} high, equivalent to 617^{mm} mercury, is supported by a pressure of 122^{mm} of mercury, which is impossible. DIXON further believes, and brings experimental evidence to support his belief, that the pressure conditions indicated by COPELAND'S manometers are local and have nothing to do with the true pressure conditions in the tube as a whole. The arguments on this point are twofold. First, it is shown that plaster of Paris long continues to absorb water and this may cause the rise of mercury in the manometers; second, the rate of transmission of water through tubes of plaster of Paris as used by COPELAND is so slow, that equalization of pressure conditions by the passage of water through a distance of 8.4^{m} is impossible.—H. HASSELBRING.

DIXON[25] describes an interesting transpiration model which will prove useful for illustration. The apparatus consists of a thistle tube closed by two parchment membranes so arranged that a lenticular cell is formed between them. Gelatin tannate is precipitated in the membranes, and the cell is filled with dry sugar. When the tube is filled with water the parchment cell becoming turgid represents the system of turgid cells which in living plants, intervenes between the water-conducting channels and the outer air. This model will act until a leak is formed in the membrane, or until the diffusion of sugar into the tube makes the liquid below isotonic with that of the cell. The actual passage of water can be rendered visible by connecting the lower end of the tube with a capillary tube running across the stage of a microscope and dipping into a beaker of water in which minute solid particles are held in suspension. It is found that the water will rise although under tension, and that even then the cell will remain turgid, owing to the fact that although the water in the cell may be in a state of tension, the dissolved substances exert a pressure. That this condition can exist in the cells of plants is shown by the following interesting experiment. A small strip

[25] DIXON, H. H., A transpiration model. Notes Bot. Soc. Trinity Coll. Dublin 1:217–224. *fig. 1.* 1905.

of tissue taken from some suitable plant is placed in the long closed arm of a J-tube. The tube is filled with water and the atmospheric pressure is removed from the short arm by means of an air-pump. The strip of tissue, in the upper part of the column of water held in tension by the weight of the lower parts, remains curved showing an osmotic pressure existing in the cells in spite of this tension.—H. HASSELBRING.

CAMPBELL[26] has continued his studies of the Araceae by investigating *Anthurium violaceum leucocarpum* and *Nephthytis liberica*. The account of Anthurium is quite like that of the usual angiosperm. The archesporium in the ovule is a single hypodermal cell, which divides periclinally. The primary sporogenous cell passes directly into the megaspore without division; and in the development of the gametophyte to the fertilization stage there is nothing worthy of remark. In the formation of endosperm there is no free nuclear division, a wall appearing with the first division, which occurs at the antipodal end of the sac, the formation of endosperm thus proceeding from the antipodal toward the micropylar end of the sac. The embryo is at first an almost globular mass of cells, with a "rudimentary" suspensor. Nephthytis proved to be quite variable in the development of the embryo sac. The archesporial cells are variable in number, and generally more than one embryo sac begins to develop. In no case did the mature embryo sac show the usual angiospermous condition, and so great was the variation that no condition could be selected as the prevailing one in the species. Among the most striking forms of mature sacs are the following: two nuclei, one at each end; a complete egg apparatus and a single antipodal nucleus; three antipodal nuclei and a single micropylar nucleus; twelve or thirteen nuclei, the three uppermost fusing; various forms of chambered sacs; fusion of contiguous sacs. The general conclusion is reached that the Araceae are relatively primitive monocotyledons.—J. M. C.

VON SCHRENK[27] has given an account of intumescences formed on leaves of cauliflowers as a result of chemical stimulation. The plants had been sprayed with copper sprays; several days after application the wart-like growths were observed on the leaves. By an experimental analysis of the conditions causing the intumescences the author finds that they are readily produced by sprays of ammonium copper carbonate and other copper salts, and in some cases with ammonia and ammonium carbonate. Soil and atmospheric conditions, including heat and water supply, had nothing to do with their formation.

It is clear that the peculiar outgrowths of leaves known as intumescences are produced by various factors in different plants. Usually they have been attributed to excessive water in the tissues due to moist atmosphere, coupled with reduced photosynthesis. SORAUER, KÜSTER, and HABERLANDT have found them in

[26] CAMPBELL, D. H., Studies on the Araceae. III. Annals of Botany **19**: 329–349. *pls. 14–17*. 1905.

[27] VON SCHRENK, H., Intumescence formed as a result of chemical stimulation. Rept. Mo. Bot. Garden **16**: 125–148. *pls. 25–31*. 1905.

certain cases due to the action of different poisons, and VON SCHRENK adds another clearly defined case due to action of specific chemical stimuli. In this connection it is interesting to note that almost simultaneously with VON SCHRENK, STEINER[28] has described intumescences on *Ruellia formosa* and *Aphilandra Porteana* which were produced regularly when the plants were transferred to an atmosphere of relatively greater humidity, while all attempts to produce them on the former plant by means of solutions, including copper sulfate failed. Aphilandra was apparently not subjected to this treatment.—H HASSELBRING.

THE MICROSPORES of *Araucaria Bidwillii* are described in a preliminary paper by LOPRIORE.[29] The intine and exine are clearly differentiated, the intine being about twice as thick as the exine. The numerous large starch grains make it rather difficult to get a clear view of the internal structures. The spores germinate best in darkness in a 12 per cent. sugar solution. The pollen tubes reach their greatest length—about ten to twenty times the diameter of the pollen grain—in eight to ten days.

At the first division of the pollen mother-cells the number of chromosomes is twelve. As the spore germinates, two lens-shaped cells are cut off from the main body of the spore. These are not evanescent, but divide and give rise to a mass of about fifteen cells. The walls of these cells soon disappear, leaving the nuclei free in the general cytoplasm of the spore. Further nuclear division then takes place until the spore contains 20–44 nuclei, 36 being the most frequent number. There are no divisions after the pollen tube begins to develop. Two nuclei in the end of the tube, somewhat larger than the rest, are regarded as vegetative nuclei, while the others are regarded as equivalent to spermatozoids. Judging from LOPRIORE's figures of the germination of the spore, the reviewer ventures to hazard the guess that the two larger nuclei are the male nuclei, while the rest of the numerous nuclei result from an unusual development of the prothallial region.—C. J. CHAMBERLAIN.

HENRY N. RIDLEY,[30] director of the Botanic Gardens at Singapore, has recorded some of his observations in the tropics on the dispersal of seeds by wind. He uses three categories: (1) winged fruits and seeds; (2) plumed fruits and seeds and (3) "powder-seed," by which he means such fine and dust-like bodies as the seeds of orchids and the spores of ferns. The nature of the observations may be illustrated from the account of *Shorea leprosula* (Dipterocarpaceae). The greatest distance the winged fruit of this species was observed to travel was about "100 yards," which is much more than the usual distance. The estimate is made that under the most favorable circumstances the species can spread only "300

[28] STEINER, R. S., Ber. Deutsch. Bot. Gesells. **23**:105. 1905.

[29] LOPRIORE, G., Ueber die Vielkörnigkeit der Pollenkörner von *Araucaria Bidwillii* Hook. Vorläufige Mitteilung. Ber. Deutsch. Bot. Gesells. **23**:335–346. *pl. 15*. 1905.

[30] RIDLEY, HENRY N., On the dispersal of seeds by wind. Annals of Botany **19**:351–363. 1905.

yards in 100 years," or it "would take 58,666 years to migrate 100 miles." The estimate is further made that a species of Dipterocarpus which ranges from the Malay Peninsula to the Philippines could not cover that distance, if there was land connection, in less than "one and a half million years." After the citation of numerous cases in each category, the general conclusion is reached that the winged seed or fruit is the slowest method of dispersal and is unable to cross any large stretch of sea; that the plumed seed or fruit, while adapted for quick dispersal over an open country, "is liable to be stopped in its migrations by dense forests;" and that "powder-seed" is adapted to the most rapid and distant dispersal.—J. M. C.

WORSDELL[31] has begun the publication of a series of papers entitled "The principles of morphology." The first one deals with the alternation of generations, and with the origin of the leafy sporophyte under which the theory of antithetic origin is approved and the opposing testimony of apogamy and apospory discredited; the conclusion being reached that "the three morphological categories of organs, viz., the leaf, stem, and root, which have persisted and remained distinct each from the other ever since the antiphytic generation attained any development, find their natural origin, therefore, in the capsule, seta, and foot or sucker respectively of the primitive bryophytic sporogonium."

The second paper[32] discusses the evolution of the sporangium. The conclusions are that the sporogonium of the primitive bryophyte is at once the homologue (1) of every type of foliar organ, (2) of every type of sporangiophore, (3) of every type of sporangium, (4) of the entire sporophyte. This is what he calls the doctrine of "variously graded" homologies. A concluding sentence is as follows: "The deductions from this idea are apparently, but only apparently, absurd; thus the sporogonium of a bryophyte must, for instance, be rigidly homologous both with an oak tree and with every single nucellus contained by every ovule of that oak tree." Appearances are not always so deceptive as the proverb would have us believe.—J. M. C.

HARPER continues to publish interesting ecological and floristic papers dealing chiefly with the flora of Georgia. One paper[33] gives an account of his explorations in 1903 in the coastal plain. A second paper[34] on Taxodium makes it pretty evident that *T. imbricarium* and *T. distichum* are specifically distinct, and that they have well defined and different characters and habitats. In noting the earlier paper, the reviewer was inclined to regard *T. imbricarium* as an ecological variety. *Pinus palustris*[35] was found at several stations at altitudes of

[31] WORDSELL, W. C., The principles of morphology. I. New Phytol. **4**:124–133. 1905.

[32] ———, The principles of morphology. II. *Ibid.* **4**:163–170. 1905.

[33] HARPER, R. M., Phytogeographical explorations in the coastal plain of Georgia in 1903. Bull. Torr. Bot. Club **32**:141–171. 1905.

[34] ———, Further observations on Taxodium. *Ibid.* **32**:105–115. 1905.

[35] ———, Some noteworthy stations for *Pinus palustris*. Torreya **5**:55–60. 1905.

1,000 to 1,500 feet in northern Georgia. A fourth paper[36] gives a list of the ferns of Georgia, with full notes, and an introduction describing the geological and other features of the state. A paper[37] on the coastal plain plants of New England gives an annotated list of plants common to Georgia and other southern states and New England. Most of the plants belong to what may be called a sandy swamp flora, and many of them are found in northern Indiana near the shore of Lake Michigan.—H. C. COWLES.

ONE OF THE LATEST PUBLICATIONS of the Royal Botanical Garden at Berlin is a guide to the "biological" collections there installed. The beginnings of this phase of the Garden activities dates back to 1890, when Dr. ENGLER[38] assumed the directorship. In the cramped space of the old garden neither the "biological" nor phytogeographical display was such as to satisfy the ambitious director. In the new garden there is sufficient space to make an adequate display possible. The guidebook is arranged systematically by topics, corresponding to the arrangement of the Garden, and interesting notes are incorporated under nearly all of the headings. Among the topics illustrated are leaf position, leaf and stem adaptations in relation to photosynthesis, adaptations that protect against excessive transpiration, plants that utilize organic substances for food, stem types, pollination adaptations, movement phenomena, adaptation for seed dispersal. Such a plan is most admirable, and should be adopted as far as possible in many places.—H. C. COWLES.

THE BOTANICAL SURVEY of Scotland, so auspiciously begun by ROBERT SMITH, has been taken up by his brother, WILLIAM SMITH.[39] In the two districts here under review, the notes were gathered largely by the deceased senior author, and have been appreciatively brought together by the junior author after recent visits to Scotland. The general plan of the Forfar and Fife maps is that of the Edinburgh and Perthaline maps, as would be expected. The maps are accompanied by a text giving a full account of the various formations, in which the regions of cultivation are included as in the earlier studies. The woods are mainly oak, birch, and coniferous. In addition there are moors, heaths, grasslands, alpine, and maritime districts within the district under survey. At the close is a very interesting summary, embracing within brief compass the chief results of the British vegetation surveys to date, arranged according to GRAEBNER'S scheme of classification.—H. C. COWLES.

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[36] ———, The fern flora of Georgia. Fern Bulletin **13**:1–17. 1905.

[37] ———, Coastal plain plants in New England. Rhodora **7**:69–80. 1905.

[38] ENGLER, A., Führer durch die biologisch-morphologischen Abteilungen des Königl. botanischen Gartens zu Dahlem. Notizblatt Königl. Bot. Gartens, Appendix XVI. pp. 66. 1905.

[39] SMITH, ROBERT and WILLIAM G., Botanical Survey of Scotland. III and IV. Forfar and Fife. Scotland Geog. Mag. **20**:617–628. 1904. *Ibid.* **21**:1–20; 57–83; 117–126. 1905.

CLEMENTS[40] has given a short account of formation and succession herbaria. The idea of herbaria based on habitats in addition to those based on taxonomic characters seems to have been suggested by DRUDE, and has now been followed out in several places. No one has worked out the idea more systematically than has CLEMENTS in the Colorado mountains, and he distributed herbaria from there in 1901. Succession herbaria illustrate the dynamics of plant formations, and are the most desirable of ecological herbaria, but the most difficult to prepare. In his Colorado work the cryptogams, apart from the ferns, have been incorporated into a separate herbarium. The paper closes with an illustrated list of Colorado plants arranged by formations; in each formation there appears first the facies, followed by the principal and secondary species of the spring, summer, and autumn aspects.—H. C. COWLES.

KÜSTER[41] takes issue with SENN, who in a recent preliminary report has concluded that the position of chloroplasts in darkness is to be accounted for by an uneven distribution of the substance chemotactically potent upon them. The author's experiments with Dictyota and Padina especially, show that under the influence of hypertonic solutions the chloroplasts arrange themselves along the side walls (*Profilstellung*), while hypotonic solutions cause them to seek the upper and lower walls (*Flächenstellung*). The change in turgor pressure of the cell is thus the direct cause of orientation movements of the chromatophores and this change may be induced by light, or by hyper- or hypotonic solutions independently of light.—RAYMOND H. POND.

MISS LATHAM,[42] Barnard College, in investigating the response of fungi to the vapor of chloroform, has reached the following conclusions: (1) when present in small quantities chloroform vapor acts as a characteristic stimulant to the growth of *Sterigmatocystis nigra* and *Penicillium glaucum;* (2) larger quantities are inimical or fatal; (3) increased growth is attended by relatively less acid formation and less sugar consumption, indicating greater economy in metabolism; (4) the time of greatest sensitiveness is at the germination of the spores; (5) chloroform acts as a stimulant purely, since it cannot be a source of carbon; (6) the effect of a given amount of the anaesthetic is greater as the temperature rises.—J. M. C.

DARBISHIRE[43] has undertaken a study of Mamillaria, especially with a view to interpreting the significance of the plant form and the spines. Observations

[40] CLEMENTS, F. E., Formation and succession herbaria. University of Nebraska Studies **4**: no. 4. pp. 27. 1904.

[41] KÜSTER, E., Ueber den Einfluss von Lösungen verschiedener Konzentration auf die Orientierungsbewegungen der Chromatophoren. Ber. Deutsch. Bot. Gesells. **23**:254–256. 1905.

[42] LATHAM, MARION ELIZABETH, Stimulation of Sterigmatocystis by chloroform. Bull. Torr. Bot. Club **32**:337–351. 1905.

[43] DARBISHIRE, O. V., Observations on *Mamillaria elongata*. Annals of Bot. **18**:375–416. 1904.

were made on the morphology, stem anatomy, root, and tubercle. The author holds that plant characters are to be regarded as useful now as formerly, and that, especially in adverse conditions, useless characters are unlikely to occur. Thus the structures of a desert plant like a cactus are presumably responses to desert conditions. DARBISHIRE does not favor the protective theory of spines, but he holds that these spines serve the purpose of light screens, whence he calls them paraheliodes.—H. C. COWLES.

PAMMEL[44] has recently published the results of his study in Iowa of the apple rust and of the fungi causing this well known disease. The account of each of five species of Gymnosporangium includes the important literature, its structure, and its polymorphism. Many original inoculation experiments are reported regarding the connection of the above species with the aecidial stage formerly included in the form genus Roestelia. As treatment the removal of the cedar trees is recommended wherever possible. Less favorable results from spraying apple trees were obtained than were reported by Emerson.[45]—E. MEAD WILCOX.

THERE IS BEGINNING to appear[46] in the *New Phytologist* a series of papers on the vegetation of various countries, the aim of which is less the presentation of the results of research than the awakening of further interest in the study of vegetation by making use of vivid personal sketches. The first papers deal with the shore vegetation of Ceylon, and there is a good account given of the typical tropical sand strand and of the mangrove and nipa formations. There are many cuts illustrating characteristic plant forms, and the description of the plant forms and formations is admirable.—H. C. COWLES.

TSCHERNIAJEW[47] finds that temperature affects the intensity of the aerobic respiration of wounded plants (onion bulbs), but not the anaerobic. This was ascertained by determining the rate of exhalation of carbon dioxid at elevated (30°–45°) and at ordinary temperatures (16°–19°). A higher temperature increases the intensity of aerobic respiration—the maximum, after wounding, appearing sooner than at ordinary temperature. Intramolecular respiration, however, at both ordinary and elevated temperatures, decreases in intensity after wounding.—RAYMOND H. POND.

COLLINS[48] has written a short account of an interesting Rhode Island bog,

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[44] PAMMEL, L. H., The cedar apple fungi and apple rust in Iowa. Bull. Iowa Exp. Stat. 84:1–36. *figs. 1–11.* 1905.

[45] EMERSON, R. A., Apple scab and cedar rust. Bull. Neb. Exp. Stat. 88:1–21. 1905. *figs. 1–9.* BOT. GAZETTE **40**:149. 1905.

[46] TANSLEY, A. G., and FRITSCH, F. E., Sketches of vegetation at home and abroad. I. The flora of the Ceylon littoral. New Phytol. **4**:1–17; 27–55. 1905.

[47] TSCHERNIAJEW, E., Ueber den Einfluss der Temperature auf die normale und die intramoleculare Atmung der verletzten Pflanzen. Ber. Deutsch. Bot. Gesells. **23**:207–211. 1905.

[48] COLLINS, J. F., Some interesting Rhode Island bogs. Rhodora **6**:149–150. 1904.

in which four species hitherto unrecorded for the state were discovered (*Andromeda polifolia, Kalmia glauca, Eriophorum vaginatum, Arceuthobium pusillum*). The black spruce is more abundant than elsewhere in the state. Obviously this is a relict vegetation, and it is interesting to know that ice remains in this bog until late in May. The Andromeda was in full bloom, while the stems were yet imbedded in thick ice, a condition surely reminding one of the far north. —H. C. COWLES.

AN INSTRUCTIVE ECOLOGICAL STUDY of the giant cactus has been made by Mrs. SPALDING.[49] It is found that changes in bulk due to varying amounts of stored water are accompanied by circumferential stem changes accomplished by a bellows-like action of the ribs, which draw closer together as the circumference decreases, and move farther apart as it increases. Variations in circumference are least pronounced at the base and top; and differences are shown between the north and south sides. These changes in no way impair the mechanical system.—H. C. COWLES.

BLANKINSHIP[50] has published an historical account of botanical work in Montana. The frontispiece is an elegant colored plate of *Lewisia rediviva*. The accounts of collecting expeditions are arranged chronologically, and the bibliography of titles dealing with the state flora, arranged alphabetically, will be very helpful to students of the vegetation of that region. BLANKINSHIP[51] has also published a supplement to RYDBERG'S *Montana flora*, and in association with H. F. HENSHALL[52] he has prepared a list of the common names of Montana plants.—H. C. COWLES.

BULLER[53] has obtained some interesting data from the study of a single-gilled fungus whose saprophytism destroys paving blocks. When grown in light or in darkness papillae protrude which in the former case develop pilei but in the latter do not. The papillae remain rectipetal and indifferent to geotropic stimuli until exposed to light, when they become negatively geotropic and positively heliotropic. The latter sensitiveness is lost, however, during the formation of the pileus, which is dependent upon sufficient illumination.—RAYMOND H. POND.

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[49] SPALDING, EFFIE S., Mechanical adjustment of the suaharo (*Cereus giganteus*) to varying quantities of stored water. Bull. Torr. Bot. Club **32**:57–68. 1905.

[50] BLANKINSHIP, J. W., A century of botanical exploration in Montana, 1805–1905; collectors, herbaria, and bibliography. Mont. Agric. Coll. Sci. Studies **1**:3–31. 1905.

[51] ———, Supplement to the flora of Montana: additions and corrections. *Ibid.* **1**:33–109. 1905.

[52] BLANKINSHIP, J. W., and HENSHALL, H. F., Common names of Montana plants. *Ibid.* **1**:113–139. 1905.

[53] BULLER, A. H., R. The reactions of the fruit-bodies of *Lentinus lepideus* Fr. to external stimuli. Annals of Bot. **19**:427–436. *figs. 30.* 1905.

BOLLETER[54] has prepared an extended morphological and physiological monograph on *Fegatella conica* (L.) Corda. The subject is treated under the headings, general considerations, structure of the thallus, structure and development of the sexual shoots (including development of archegonia, antheridia and fertilization), development of the sporogonium and spores, germination of spores, development of the thallus, and asexual reproduction. It is a very complete study of the life-history and will be useful for reference.—C. J. CHAMBERLAIN.

LEAVITT,[55] in an interesting paper dealing with monstrosities in Drosera, Gentiana, and Saxifraga, uses the term "morphic translocation" in speaking of characters of one organ which appear suddenly on another organ, but without atavistic significance. The gentian spoken of had a petaloid fringe on the carpel, and the Drosera had glandular tentacles on perianth and carpels. The possible significance of such translocations, as well as the broader topic of the use of teratological data, is discussed rather fully.—H. C. COWLES.

OLSSON-SEFFER[56] tells of the plans of the Danish ecologist, M. P. PORSILD, for the establishment of a permanent laboratory in Greenland. The realization of these plans, thorough and yet modest from the standpoint of expenditure, would be of untold value to science, and it is to be hoped that the Danish government will grant PORSILD's request. This seems likely, in view of the liberality of Denmark to previous botanical explorers in Greenland.—H. C. COWLES.

WHILE LIGHT SEEMS to have little or no influence on the germination of most seeds, it favors the germination of some, and in the case of a very few (as Viscum, *Drosera capensis*), light is necessary for germination. Only in the case of *Acanthostachys strobilacea* had light been found to hinder germination. Now REMER[57] adds another plant, *Phacelia tanacetifolia*, to Acanthostachys. The ecological significance of such aberrants is unknown.—H. C. COWLES.

W. H. LAWRENCE[58] has published a short popular account of the Erysiphaceae, together with keys and descriptions of the genera and species found in the state of Washington. Notes are also presented upon six diseases of cultivated plants in Washington due to species of this well-known family. Spraying with Bordeaux mixture, cupram, or flowers of sulfur is recommended as the best means of controlling these mildews.—E. MEAD WILCOX.

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[54] BOLLETER, E., *Fegatella conica* (L.) Corda, Eine morphologisch-physiologisch Monographie. Beih. Bot. Centralbl. **18**:327–408. *pls. 12–13.* 1905.

[55] LEAVITT, R. G., On translocation of characters in plants. Rhodora **7**:1–17. 1905.

[56] OLSSON-SEFFER, P., A biological station in Greenland. Science **21**:189–191. 1905.

[57] REMER, W., Der Einfluss des Lichtes auf die Keimung bei *Phacelia tanacetifolia* Benth. Ber. Deutsch. Bot. Gesells. **22**:328–339. 1904.

[58] LAWRENCE, W. H., The powdery mildews of Washington. Bull. Wash. Exp Stat. 70:1–16. *figs. 22.* 1905.

COCKAYNE[59] has found that *Discaria Toumatou*, a New Zealand xerophytic shrub that normally has long pungent spines, fails to develop these spines in moist chamber cultures. It is believed that the juvenile leafy shoots instead of spines would continue indefinitely in such conditions. He regards these facts as highly favorable to the xerophytic rather than the protective theory of thorns.—H. C. COWLES.

HARSHBERGER[60] proposes that the term zone in plant geography be restricted to broad belts determined by latitude, conforming to the law of priority as well as dominant usage. Mountain zones he would term belts; concentric pond zones, circumareas; submerged shore zones, shelves; strand, river, or prairie edge, strips; island zones, girdles; and vertical forest zones, layers.—H. C. COWLES.

HARSHBERGER has been making further floristic studies on the North American flora. One paper[61] deals with the comparative age of the various elements in eastern North America, and there is a chart that shows the supposed relative time of appearance of these elements from the Miocene until now. A second paper[62] deals briefly with centers of dispersal.—H. C. COWLES.

SWELLENGREBEL[63] finds something to attract him in the dunes of the Netherlands in spite of H. BLINK's assertion that they have no true dune plants, and that if present they would be of no interest! The plant societies noted are those of the sea dunes, the gray dunes, and the dune hollows. Detailed notes are given concerning the source of the dune flora.—H. C. COWLES.

IN A LECTURE before a convention of practical farmers at Breslau, January, 1905, TSCHERMAK[64] gave a clear exposition of the recently discovered laws of inheritance and their significance for practical agriculture. He also included a brief discussion of variation and mutation.—G. H. SHULL.

A GOOD ACCOUNT[65] of the Desert Botanical Laboratory and of the more striking vegetation in its vicinity has been published by Professor LLOYD.—H. C. COWLES.

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[59] COCKAYNE, L., On the significance of spines in *Discaria Toumatou* Raoul (Rhamnaceae). New Phytol. **4**:79–85. 1905.

[60] HARSHBERGER, J. W., Suggestions toward a phytogeographic nomenclature. Science N. S. **21**:789–790. 1905.

[61] HARSHBERGER, J. W., The comparative age of the different floristic elements of eastern North America. Proc. Acad. Nat. Sci. Phil. **1904**:601–615.

[62] ———, Original centers concerned in North American plant dispersal. *Ibid.* **1905**:2.

[63] SWELLENGREBEL, N., Ueber niederländische Dünenpflanzen. Beih. Bot. Centralbl. **18**[2]:181–198. 1905.

[64] TSCHERMAK, E., Die neuentdeckten Vererbungsgesetze und ihre praktische Anwendung für die rationelle Pflanzenzüchtung. Reprint from Wiener Landw. Zeitg. nos. 17, 18, 19. pp. 31. 1905.

[65] LLOYD, F. E., A botanical laboratory in the desert. Pop. Sci. Monthly **66**: 329–342. 1905.

NEWS.

MR. F. J. SEAVER has been appointed professor of botany in Iowa Wesleyan College, at Mt. Pleasant, where he hopes to continue his study of Discomycetes.

DR. R. H. TRUE, in charge of drug-plant investigations for the U. S. Bureau of Plant Industry, is paying special attention to the culture of paprika peppers. The crop of the past season is reported as extremely satisfactory.

PROFESSORS MACBRIDE and SHIMEK, of the University of Iowa, spent part of last summer in the southwestern deserts, especially in the Salton basin. The University herbarium now contains a fairly complete representation of the flora of New Mexico and Arizona.

GEBRÜDER BORNTRAEGER are proposing to reprint certain missing parts of the *Jahrbücher für wissenschaftliche Botanik* so as to offer complete sets of the first forty volumes, provided there are a sufficient number of subscribers at *M* 1250 for the set. We trust they will be encouraged to execute the project.

MR. L. H. DEWEY, in charge of fiber-plant investigations, U. S. Bureau of Plant Industry, has recently distributed to agricultural colleges and other technical schools sets of the principal plant fibers used in the textile industries in this country. Until exhausted, these sets will be forwarded to schools and colleges where they will be of service in teaching economic botany or commercial geography.

THE DEPARTMENT of botany of Purdue University has this year added courses in forestry, administered by Professor STANLEY COULTER, covering two years' work, and including instruction in timber physics under the direction of Professor W. K. HATT, in charge of timber tests for the U. S. Forest Service. With prerequisites covering Freshman and Sophomore work, the initial enrolment is thirteen. The University of Iowa is also extending its courses along forestry lines.

THE SYSTEMATIC botanical work of the U. S. Bureau of Plant Industry has recently been brought together and put in charge of Mr. F. V. COVILLE. Heretofore, considerable work of this character has been carried on in several offices of the Bureau, more especially in that of the Agrostologist, where systematic studies of grasses have been conducted for many years. The grass collections have also been placed under the charge of Mr. COVILLE, and Mr. A. S. HITCHCOCK, in general charge of systematic work on grasses, has been assigned to the office of the Botanist for the continuance of this work.

AT THE University of Nebraska changes have been made which provide better accommodations for the herbarium (now containing about 100,000 specimens) and the botanical library. The plant houses, hitherto shared with the department of horticulture, are to be under the full control of the department of botany. A new botanical laboratory has been fitted up in connection with the School of Agriculture and the Experiment Station, in the recently completed Agricultural Hall on the University Farm. While part of the general depart-

ment, this laboratory is specifically in the charge of Dr. F. D. HEALD. Dr. F. E. CLEMENTS is to give courses in ecology as part of the larger division of plant physiology of which he was recently appointed associate professor.

FROM THE *Journal* of the New York Botanical Garden we learn that Dr. and Mrs. N. L. BRITTON, accompanied by Mr. STEWARDSON BROWN, curator of botany in the Philadelphia Academy of Natural Sciences, spent three weeks in Bermuda in September, bringing back a large collection of plants, live and dried, in all about 3,000 specimens.

DR. P. A. RYDBERG spent two months last summer in collecting about Salt Lake City, Marysvale, and Nephi, Utah.

Mr. GEORGE V. NASH has recently returned from an exploring expedition in the interior of Hayti, reaching some regions hitherto unvisited by any botanist and bringing back large quantities of live plants, seeds, and preserved material.

DR. FORREST SHREVE is spending the winter at the tropical laboratory of the New York Botanical Garden, Cinchona, Jamaica, having been appointed a laboratory assistant of the Garden and Bruce Fellow of Johns Hopkins University.

THE FOLLOWING movements among the staff of the U. S. Bureau of Plant Industry have been reported at our request:

DR. W. O. RICHTMANN has returned from a trip to California, undertaken in the interests of camphor and poppy investigations.

MR. W. F. WIGHT has just returned from Europe, where he spent four months in studying type specimens of plants in various herbaria.

MR. F. H. HILLMAN recently visited the Pacific coast in order to study the species of dodder which are so troublesome in alfalfa and clover fields.

MR. G. FRED KLUGH spent several months in Idaho and Nevada studying the relation of poisonous plants to the sheep trouble known as "bighead."

MR. S. C. HOOD, who has been in charge of the Vermont station for drug-plant investigations, at Burlington, has returned to Washington for the winter.

PROFESSOR H. PITTIER is about to start on an exploring trip of four or five months' duration in western Columbia, with a special view to a study of the cottons of that region.

MR. T. B. YOUNG has returned to Washington after a season's work at Ebenezer, S. C., where he has been in charge of the drug-plant farm, in cooperation with Mr. J. W. KING.

MR. EDGAR BROWN recently returned from an inspection of the more important seed laboratories of England, France, Netherlands, Germany, Austria-Hungary, and Switzerland.

MR. W. W. STOCKBERGER recently made a trip through the hop-producing sections of the Pacific coast and the state of New York, where the conditions of brewing and of curing hops have been studied.

DR. J. W. T. DUVEL is spending some time in Ohio and Illinois investigating the curing of seed corn. It has been found that by proper treatment seed corn of high vitality can be assured at planting time.